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Developments at Ninth International Conference on Water Pollution Research Held at Stockholm, Sweden on June 12-16, 1978

(U.S.) United States of America National Committee for
Representation of the United States to the
International Assn. on Water Pollution Research

Prepared for

Environmental Research Center, Cincinnati, OH

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DEVELOPMENTS AT NINTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH

Stockholm, Sweden
June 12-16, 1978

Prepared For

Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C.

By

United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research

September 1978

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16. ABSTRACT

This report is an interpretive analysis of formal and informal developments at the Ninth International Conference on Water Pollution Research held in Stockholm, Sweden, on June 12-14, 1978, and has been prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research.

Information of particular significance concerning developments in international water pollution research included:

1. In the developed countries the emphasis is changing from energy intensive physical-chemical processes back to biological systems for removal of both organic matter and nutrients from wastewaters.
2. A chemical-biological system for the removal of both organic matter and nutrients from wastewaters requires a design using mechanistic principles and parameters which integrate both the chemical and biological processes rather than treating them separately.

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United States of America National Committee
for Representation of the United States to the
International Association on Water Pollution Research

September 1978

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INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH

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September 26, 1978

Dr. James E. Smith, Jr.
Environmental Engineer
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Dear Dr. Smith:

This report on "Developments at the Ninth International Conference on Water Pollution Research" is submitted in accordance with provisions of EPA Grant No. R805756010 to the United States of America National Committee for Representation of the United States to the International Association on Water Pollution Research. The report contains an analysis of formal and informal developments at the Conference which are of special relevance to water pollution control activities in the United States.

The objective of the report is to promptly bring current water research developments from around the world to the attention of the Office of Research and Development. The report contains interpretation of developments at technical sessions at the Stockholm IAWPR Conference and reports of information transfer on water research and development which will not be contained in the official Conference Proceedings when ultimately they appear.

Members of the USA National Committee appreciate the support from the several programs in the Office of Research and Development which enabled preparation of this report. Please feel free to contact the Committee for

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9th International Conference on Water Pollution Research, Stockholm, Sweden - June 12-16, 1978

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elaboration of specific details contained in the report which are of interest to EPA personnel.

Sincerely,

Richard I. Dick, Chairman
For USANC Coordinating Subcommittee:

Richard S. Engelbrecht
Richard I. Dick
John B. Nesbitt
David G. Stephan

RID:add

Enclosures

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EXECUTIVE SUMMARY

Beginning in 1962, the International Association on Water Pollution Research has held an international conference biennially. This report is an interpretive analysis of formal and informal developments at the Ninth International Conference on Water Pollution Research held in Stockholm, Sweden, on June 12-14, 1978, and has been prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research.

The Conference papers, complete with formal and informal floor discussion, will be published in the future. Because of this, this report does not contain the formal papers or verbatim presentations of discussions. Rather, this report was prepared by the official U.S. participants in the Conference as a critical analysis of formal and informal developments at the Conference which were deemed to be of potential interest to the U.S. Environmental Protection Agency.

Important information concerning developments in international water pollution research was obtained both from the formal Conference sessions and, perhaps even more importantly, from informal information exchanged outside the formal meeting rooms. Of particular significance were the following:

-- two concepts of signal importance because of their mention in each of five sessions:

1. In the developed countries the emphasis is changing from energy intensive physical-chemical processes back to biological systems for removal of both organic matter and nutrients from wastewaters.

2. A chemical-biological system for the removal of both organic matter and nutrients from wastewaters requires a design using mechanistic principles and parameters which integrate both the chemical and biological processes rather than treating them separately.

-- greater interest in controlling the discharge of nutrients to receiving waters than in controlling the discharge of small amounts of organic compounds.

-- the increasingly evident close relationship between potable and wastewater treatment in terms of both public health and the selection of treatment processes.

-- that worldwide interest in nitrogen removal stems principally from public health considerations with cultural eutrophication being of secondary concern.

-- the disclosure that there is available in Sweden an extensive data base on the performance and sludge characteristics of over 600 Swedish sewage treatment plants which are precipitating phosphorus by a variety of chemical and chemical-biological treatment processes.

-- a quite thorough paper on combined physical-chemical-biological treatment systems rich with insights into their performance.

-- reports on significant research on factors influencing uptake and release of phosphorus in biological wastewater treatment systems underway in South Africa and Scandanavian countries.

-- information on the upgrading of treatment ponds through chemical additions to improve treatment efficiencies and to achieve phosphorus removal.

-- use of lime-magnesium coagulants for upgrading oxidation pond performance.

-- presentation of useful quantitative information on ozonation reactions and development of a model for oxidation by ozone.

-- a report on the effects of oxidation by ozone or hydrogen peroxide on the creation and destruction of chloroform precursors in water subsequently to be chlorinated.

-- a statement that a method for generating ClO_2 at one-fourth the cost of present methods is under development in Canada.

-- description of a new instrument for measuring the concentration of activated sludge in aeration tanks.

-- a technique for quick characterization of thickening characteristics of sludge using a centrifuge test.

-- floc particle size should be given more emphasis in the design of granular media filters.

-- data on the chemical and physical components of the major liquid waste streams from steam-electric power generation.

-- a method for predicting the quality of storm run-off by studying existing long-term sewage treatment plant records.

-- papers from several countries indicating that the atmosphere may be a significant nonpoint source of nutrients in surface waters.

-- innovative nonpoint pollution control techniques practiced in various European countries including installation of plastic partitions in lakes, use of lattice pavements, architectural landscaping, and land use management.

CHAPTER I

INTRODUCTION

Background

This report is an interpretive analysis of formal and informal developments at the Ninth International Conference on Water Pollution Research held in Stockholm, Sweden, on June 12-16, 1978. The International Association on Water Pollution Research Sponsors such a conference biennially. This report was prepared for the U.S. Environmental Protection Agency by the U.S.A. National Committee for Representation of the United States to the International Association on Water Pollution Research.

The International Association on Water Pollution Research (IAWPR) is a non-governmental professional organization with the goal of advancing water pollution research worldwide to enhance the quality of the earth's water resources. It is governed by representatives of national committees of member countries. Each national committee, as a condition of membership in IAWPR, represents the water pollution research-related professions in the respective country.

The International Association on Water Pollution Research recognizes the United States of America National Committee (USANC) as the national organization representing American water pollution research interests in IAWPR. USANC is sponsored by five major professional societies with interests in water pollution research: (1) American Chemical Society; (2) American Institute of Chemical Engineers; (3) American Society of Civil Engineers; (4) Association of Environmental Engineering Professors; and (5) Water Pollution Control Federation. Each of these professional societies provides financial support to USANC for membership in IAWPR and appoints two delegates and two alternate delegates to serve on the U.S.A. National Committee.

International conferences of IAWPR have been held biennially since 1962. Conferences prior to the 1978 Stockholm Conference were held in London, Tokyo, Munich, Prague, San Francisco, Jerusalem, Paris, and Sydney. The 1982 conference will be held in Toronto and the 1984 conference in Capetown. The conferences represent the largest international gathering of researchers in water pollution control and, thereby, provide an invaluable mechanism for the exchange of water pollution control information by both formal and informal means.

The purpose of this report is not to present a verbatim record of the Conference. Papers complete with formal and informal floor discussion and responses from authors will, in time, be published as separate proceedings and in one of the two professional journals of IAWPR, Progress in Water Technology. Rather, the purpose of the report is to present a critical analysis of formal and informal developments at the

Conference which are of potential interest to the U.S. Environmental Protection Agency. The report represents an assessment by American participants in the Conference of the significance of developments at the Conference. Contributions of individual authors from various countries of the world are considered in the context of the reception which they received from discussers and the international audience. The analysis is not limited to formal conference developments, but includes developments from the informal exchanges between engineers and scientists from various countries which inevitably occur at such conferences.

The agenda for the Stockholm Conference was developed by the Program Committee of IAWPR from papers submitted from around the world in response to invitations to submit manuscripts of papers related to advanced wastewater treatment, sludge treatment, pollution from urban runoff, or studies of receiving waters. Reprints of papers selected for the program were available to participants in advance of the Conference, and only abbreviated summaries of the papers were presented by the authors in Stockholm. Formal discussers were selected prior to the Conference to prepare critical analyses of each paper. Additionally, appreciable informal discussion of the papers and of the formal discussions occurred. Appendix I contains the program for the Conference and provides additional information on the conduct of the session.

Report Development

This report was prepared by those American participants in the Stockholm Conference who presented papers, presented prepared discussions of research work described by others, chaired or recorded sessions and workshops, and/or participated in IAWPR Governing Board activities who elected to participate in the project. Development of the report was coordinated by a Subcommittee of USANC consisting of the USANC officers (Richard I. Dick, David G. Stephan, and Richard S. Engelbrecht) together with a USANC Committeeman (John B. Nesbitt).

Prior to the Conference, the USANC Coordinating Subcommittee ascertained the interest of participants in cooperating in the development of this report and solicited expressions of interest in reviewing particular sessions at the Conference. Then, assignments for coverage of all the sessions were made as indicated in Appendix II. Appendix III contains the instructions given to participants in development of this report.

Reports by the individual participants are included in Chapter II. Aside from minor editing to render the reports compatible with the general format and to eliminate items unrelated to water pollution research, the reports are published here as received from the authors. The reports thus represent a critical assessment by American water pollution control researchers of those sessions of the Conference which received their special attention. The reports appear under the by-line of the reviewers and represent their personal views -- not necessarily the views of the Coordinating Subcommittee or USANC.

Highlights of Chapter II as perceived by the Coordinating Subcommittee are summarized in Chapter III. Additionally, information submitted by individual participants on developments at the Conference unrelated to their sessions are summarized in Chapter III. The Executive Summary is an abbreviated version of Chapter III.

Users of the report will find the Table of Contents together with the Key to Reviews useful in locating in Chapter II the discussions of particular papers or workshops. Additionally, Appendix I should be useful in gaining a perspective on the Conference and on the contents of Chapter II.

CHAPTER II

I. SESSION

A. Day: Monday, June 12, 1978
Hall: A
Time: 2:00 to 5:00 pm

B. Theme of Session: Adsorption in Wastewater Treatment

II. REVIEWER

A. Name: Charles R. O'Melia

B. Position and Affiliation: Professor of Environmental Sciences and Engineering
Department of Environmental Sciences and Engineering
University of North Carolina
Chapel Hill, NC

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 1: "Carbon Adsorption as an Advanced Wastewater Treatment Process," by D. L. Ford (USA)

The author noted that some organic compounds are adsorbable on activated carbon while some are not, and that some organic compounds are readily biodegraded while some are not. Furthermore, many of the biodegradable compounds are poorly adsorbed, while many adsorbable compounds are resistant to biodegradation. This perspective indicates that the production of wastewater effluents with low BOD and COD concentrations requires a combination of biological treatment with carbon adsorption.

The author provided some support for this conclusion by citing experiences at several full scale installations. For municipal wastewaters, production of effluents with BOD concentrations less than 5 mg/ℓ and COD concentrations less than 20 mg/ℓ was achieved when effective biological treatment preceded carbon adsorption. For industrial wastewaters, additional factors were noted. For example, the failure of activated carbon to treat a refinery waste was ascribed to poor pretreatment for the removal of oil and grease.

The author concluded by noting several present and proposed innovative techniques to combine the use of activated carbon with other processes to produce effluents low in BOD and COD. One example, the addition of powdered activated carbon to activated sludge processes, was considered to provide better COD removal, improved settling, and enhanced nitrification.

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A.2 Paper No. 4: "The Use of Activated Carbon for Chromium (VI) Removal," C. P. Huang, A. R. Bowers (USA)

This paper contains an analysis of the mechanisms of interaction between activated carbon and also some proposed treatment schemes for wastewaters containing Cr(VI). The mechanistic analysis is based on kinetic data obtained in batch laboratory experiments. The presentation of the research included in addition some preliminary results of Cr(VI) removal observed in laboratory packed bed experiments.

The authors propose a model for the removal of Cr(VI) by activated carbon that involves both adsorption and reduction. Initially, Cr(VI) is considered to react rapidly with H-type carbon to produce Cr(III) which is then released to solution. This is followed by a slower reaction in which Cr(VI) and, to a lesser extent, Cr(III), are adsorbed. The initial reduction reaction is affected by mixing in the batch systems while the subsequent adsorption reaction is not affected significantly by mixing. Empirical rate expressions are presented for both reactions. The concentrations of Cr(VI), carbon, and protons affect both reactions.

The data presented for continuous column operations were interesting but difficult to interpret quantitatively. Short carbon columns appeared to reduce Cr(VI) to Cr(III) and provide poor removal of total chromium. Longer columns did provide significant removal of both Cr(VI) and total chromium.

The authors propose three processes for removal of chromium. All are plausible; none has been tested sufficiently to date. One process is an attempt to use differences between H and L carbons. H carbons adsorb acids, have a relatively high ZPC (zero point of charge), and can reduce Cr(VI) to Cr(III). L carbons can adsorb bases, have a low ZPC, and may, in the authors' judgment, be effective adsorbers for Cr(III). If correct, this analysis suggests the use of H and L carbon beds in series. Here, Cr(VI) is reduced to Cr(III) in the first (H-type) bed, and the Cr(III) is removed by adsorption in the second (L-type) bed. Regeneration has not been addressed to date.

A.3 Paper No. 7: "Purification of Pulp Bleaching Wastewater with Aluminum Oxide," H. Ullrich (Federal Republic of Germany)

The author presented the results of a full-scale treatment plant using adsorption on aluminum oxide followed by activated sludge for the treatment of pulp bleaching effluent from a mill discharging to Lake Constance. The adsorption process removed many nonbiodegradable compounds of high molecular weight. The biological process then removed degradable compounds of lower molecular weight that are difficult to adsorb. The activated alumina columns removed 35 percent of the BOD, 73 percent of the TOC, and 96 percent of the color applied to them. Removal was ascribed to adsorption on the solid aluminum oxide and possible precipitation with aluminum ions dissolved from the adsorbent.

B. Prepared Discussion

B.1 Paper No. 1

Waller presented the formal discussion of Paper No. 1. He supplemented the American experiences presented by Ford with techniques and applications using powdered and granular activated carbon in Europe.

A new process is under development in Germany in which powdered carbon is used with plastic beads in a storage-filtration-treatment system. In an upflow process, plastic beads permit powdered carbon to be held in suspension and adsorb organics. When the carbon is exhausted, it is removed from the bottom of the system by downflow operation. No results were given.

Treatment of municipal wastewaters in Europe by physical-chemical treatment using granular carbon has encountered some problems due to the high strength (i.e., high BOD and COD) of European sewage. For industrial wastes, granular activated carbon has been used for removing herbicides, pesticides, and carcinogens for many years.

Economics has been a factor of concern in the selection of activated carbon as a treatment process. Regeneration can provide economies. First, central regeneration can produce economies of scale. Second, some industries have found regenerated carbon to be more effective than virgin carbon. Finally, regeneration may not be accomplished properly, leading to unnecessary costs in the actual adsorption process.

In his reply, Ford noted that further research is needed to determine the effects of waste strength on the kinetics of adsorption by carbon. He indicated a preference for costs expressed on the basis of a unit of BOD or COD removed, rather than per unit volume (e.g., m^3) of wastewater treated. Finally, he agreed that economies of scale can make central regeneration attractive if geography permits.

B.2 Paper No. 4

Weber (USA) presented the formal discussion of Paper No. 4. He indicated general agreement with the authors about the possibility of using activated carbon to remove heavy metals from wastewaters in selected applications. His discussion concentrated on areas in the paper in which the authors had, in his opinion, made conceptual mistakes.

Weber noted that the solubility diagram for Cr(III) as a function of pH (discussed as Figure 3 in the authors written text but also titled Figure 2 in the paper) considered only the reactions of Cr(III) with water and subsequent precipitation of $Cr(OH)_3 \cdot nH_2O$. In most industrial plating wastes, however, other ligands are present which could increase the solubility of Cr(III) and also alter the speciation in solution. He noted that the authors incorrectly described H and L carbons in some areas of their text, but used these terms correctly in their presentation. H carbons adsorb acids, L carbons adsorb bases.

Weber strongly criticized the authors' two-regime reaction scheme for Cr(VI) and activated carbon, i.e., a fast reduction of Cr(VI) followed by a slower adsorption of Cr(VI). He noted that the batch kinetic data of the authors are also consistent with sequential rate transport processes, in which external film diffusion is followed by interparticle diffusion. He considered that adsorption and reduction occur concommitantly. If this is so, the authors' kinetic expressions and their conclusions based on these rate expressions are in doubt.

In his reply, Huang agreed with Weber that the presence of complexing agents in wastewater would alter the solubility and speciation results for Cr(III) presented in the paper. He also agreed that reduction and adsorption of Cr(VI) can occur simultaneously. He then proposed that reduction is rapid in the early stages, but slows as Cr(III) is produced and accumulates in solution. This would then leave Cr(VI) adsorption as the major reaction after a time. Bowers (USA), coauthor of the paper, indicated that the authors had reexamined their data since writing the paper. The reduction of Cr(VI) was described by measuring the production of Cr(III) in the first stage. The results led to some modified rate expressions.

B.3 Paper No. 7

Meloni (Finland) presented the formal discussion of Paper No. 7. He suggested that all adsorption processes for the treatment of pulp bleaching effluents function best at low pH, whether the adsorbent is aluminum oxide, activated carbon, or synthetic adsorption resins. While the pH of the effluent is not noted in the actual paper, Meloni presumed that it was about 2.5. The color of pulp bleaching effluents decreases as the pH is lowered, and the color bodies (i.e., the lignin compounds) precipitate from solution. Hence, it is possible that some of the removal of color ascribed to aluminum oxide was accomplished by precipitation at low pH.

Meloni expressed concern about the high costs of the process and questioned its economic viability in the future.

In his reply, Ullrich stated that the pulp bleaching effluent had a pH from 2.5 to 3.5, and that the adsorption process did not function at pH greater than 4. With regard to costs, he stated again the results in his paper which conclude that the costs of treating about equal the fines for discharging unsuitable effluents. He indicated that costs might be lowered by reducing the amount of water to be treated as in a closed system.

C. Floor Discussions

C.1 Paper No. 1

Hrudey (Canada) noted that chlorination of wastewaters is often required. He suggested the use of chlorine before carbon treatment in order to allow the carbon to remove both the chlorinated organics that form in chlorination and also the residual chlorine itself.

Shuval (Israel) commented about the costs of activated carbon treatment. Given the objective of protecting the public health, the marginal extra costs incurred in improving water quality were considered to be small by Shuval. The removal of toxic organics and other toxicants can be afforded in his judgment. Public education that only a small marginal price is involved should be undertaken.

Hart (South Africa) asked about the BP countercurrent pulsed bed system described in the paper. Ford had suggested that some oil had probably clogged the pores of the carbon, and that a 40 percent reduction in iodine number had been noted in regeneration. Hart suggested that overgeneration could have caused these effects, and could have been rectified with relative ease. In comparing countercurrent with fixed bed downflow operation, Hall inquired about the average loss of carbon in the upflow unit, and about its causes (attrition, regeneration, and transportation). He also inquired about the percentage of fines in the upflow system.

Weber (USA) agreed with Ford's conclusion that those compounds that are least amenable to adsorption are generally amenable to biological degradation. He suggested that a new application of biological treatment with activated carbon, namely the integration of both processes in a single reactor, deserved additional attention. In one reactor, one can accomplish the biological oxidation of low molecular weight compounds as well as the adsorption of those materials that are resistant to degradation. The process suggests economies. Weber agreed with Shuval with regard to the importance of activated carbon in water and wastewater treatment. Such systems, however, must be properly designed. Weber indicated that biological growth will occur in carbon columns whether or not one designs for it. If it is not taken into account, problems can result. Examples include production of H_2S, development of anoxic conditions, and poor degradation of low molecular weight compounds. Designs should provide for oxygenated conditions throughout the adsorption system. Weber disagreed with Ford's statement that low temperatures improve adsorption. The extent of adsorption is increased as temperature decreases, but the rates decrease with reductions in temperature. Since kinetics can be very important in designing carbon systems, temperature effects on kinetics can be important.

Author's Reply - Regarding Hrudey's comments, Ford agreed that chlorination before carbon treatment may have some merit. A possible limitation (also noted by Hrudey) is the formation of additional chlorinated hydrocarbons by adding chlorine at a point where organics have a higher concentration. A second limitation is that chlorine can reduce the biological population in the carbon bed and thus reduce its ability to support biodegradation. Prechlorination may be required in some cases if poor design has led to biological plugging of the bed. It is difficult in design to control the biological population adequately so that degradation occurs while anoxic conditions and plugging are prevented.

In response to Shuval's comments, Ford concurred that the use of activated carbon is desirable for treating drinking waters. With regard to minimizing the use of cost effectiveness when considering the removal of carcinogens, one simply cannot argue. Nevertheless, the facts and limits of economics must be considered.

In answering Hart's questions, Ford indicated that overregeneration might be a possibility in the BP plant where oil produced problems. He indicated that carbon losses can be expected to be in the range of 5 to 15 percent per cycle.

In addressing Weber's comments, Ford began by expanding his comments on the importance of biological treatment in conjunction with carbon treatment. The new plant in Cleveland, Ohio, is a completely physical-chemical plant. This is primarily because of space limitations. It is expected that the effluent will contain 15-30 mg/ℓ of BOD and 30-70 mg/ℓ of COD. It is important to understand that physical-chemical treatment of municipal wastewaters cannot consistently produce effluents of 5 mg/ℓ BOD and 10 to 15 mg/ℓ COD. The inclusion of industrial wastes can further complicate the process.

Ford considers that the future in wastewater treatment technology lies in combined biological-carbon systems. Powdered activated carbon provides one step in the right direction. An added benefit is enhanced nitrification. Here, the *Nitrosomonas* and *Nitrobacter* bacteria may develop on the large solid surface available and provide good conversions even during cold weather.

In Ford's experience, temperature has little effect on carbon adsorption in the 13 to 23°C range. It is possible that within this range it may have occasional effects on a few wastewaters. Outside of this range it may have effects on many wastewaters.

C.2 Paper No. 4

Pomeroy (USA) questioned the validity of the objective of removing total chromium in wastewater to extremely low levels, such as the 5 μg/ℓ required by some for discharge to Pacific Ocean waters. He noted that this subject is outside the scope of the research presented by the authors, but he considered that it was a useful practical context to apply to the subject of chromium removal. Pomeroy indicated that chromium is an essential element in human and plant nutrition. It is distributed extensively in nature, averaging about 200 ppm in the earth's crust. While Cr(VI) is a poison, Cr(III) is a different chemical species with no significant toxic effects. Pomeroy questioned the usefulness of a nondiscriminatory category of heavy metals in wastewater effluents without regard to their occurrence in nature or the differences in their impacts.

Huang declined to comment on these observations and agreed that they were outside the scope of the research in the paper.

C.3 Paper No. 7

There was no floor discussion of this paper.

D. Other Observations and Comments

Most observations and comments are summarized in the prepared and floor discussions described previously in Sections III-B and III-C of this report. Attendance at the three papers was good, with the largest attendance and the greatest interest given to Paper No. 1. Based on this and on discussions later in the conference, I judge that international and American interests in combined biological-carbon systems for both water and wastewater treatment are very strong. This is clearly an area where innovative research is needed.

IV. CRITIQUE OF SESSION

Paper No. 1 was a description of experiences in actual plants, combined with an attempt to generalize from these observations qualitatively using basic concepts. The discussions of the paper were similar in nature and in scope. There was general agreement that biological-carbon systems have an important place in present and future wastewater technology, and a great variety of specific cautions about the limitations of carbon.

This paper is not a research contribution. It does provide important examples of the applications and limitations of activated carbon. In my judgment, some of the mechanistic interpretations of these observations by the authors and the discussers are plausible but not rigorously substantiated. Hence, extrapolation of the results of these case histories to other situations is risky. There is a clear and real need for research in this emerging area. In my judgment, this research will provide more long range benefits if it is theoretical or conceptual in its aims.

Paper No. 4 addressed a useful problem, viz., the application of activated carbon for the removal of toxic metals from wastewater. Its approach was theoretical; observations were confined to laboratory systems. In my judgment the paper provided a marginal contribution to this subject. The results are only preliminary and the concepts used are debatable. This is clearly a research paper, but not an excellent one.

Paper No. 7 provided a comprehensive presentation of a single case history. The presentation included both removal efficiency and cost effectiveness. No conceptual analysis was attempted; in my judgment this is appropriate for cases of this type. This paper is also not a research contribution. In my judgment it provides some useful questions for researchers to address in seeking to generalize the results. While it may also provide a base for the design of alumina columns for other pulp bleaching effluents, lack of an understanding of the process will hinder direct application.

There is certainly a need in a conference of this type of combining practical experience with research contributions. In my judgment, the practical experiences presented in the papers and discussions of this session outweigh the theoretical contributions. This is unfortunate, because generalizations based on practical experience are greatly facilitated by the use of sound concepts.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The following conclusions are suggested by the papers in this session. They point more toward future studies than to immediate application.

1. Adsorption processes are being used now and will be used more extensively in the future for wastewater treatment throughout the world.

2. Actual designs will vary depending on such factors as the water quality standards to be met, the strengths of the wastes, and the feasibility of regionalization of the treatment plants and the regeneration facilities.

3. Biological-carbon systems are considered to have promise in many countries including the USA. Research is needed to understand how they function, and to permit the biological degradation and physical adsorption processes to be integrated effectively. New developments in technology can also be anticipated.

4. Regardless of the theories or the technologies that may be developed, laboratory and pilot plant studies will be needed to provide a base for the design of carbon and biological-carbon systems for industrial waste applications.

I. SESSION

A. Day: Monday, June 12, 1978
Hall: B
Time: 2:00 to 5:00 pm

B. Theme of Session: Nitrification, Analysis of Pollution Sources and Mixing Analysis

II. REVIEWER

A. Name: Peter A. Krenkel

B. Position and Affiliation: Executive Director
Water Resources Center
Desert Research Institute
University of Nevada, Reno
Reno, NV

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 2: "Study of the Nitrification of Surface Water," by Y. Richard, L. Brener, G. Martin, C. Leblanc (France)

The investigation was concerned with the removal of ammonia from surface waters intended for utilization as a potable water source. A description of the need for ammonia removal in French drinking water supplies was presented, which indicated that greater concentrations of ammonia are found in French water supply sources than in those of the United States. Two reasons were given to justify the research described, one being associated with the cost of removing ammonia over 2 mg/ℓ by the conventional breakpoint chlorination process, and the other because of the relatively new knowledge of toxicity to the biota associated with the use of chlorine.

The prime objective of the study was to determine the feasibility of using submerged filters for ammonia removal from the water supplies of France. In accomplishing this objective, the effects of filtration rate, retention time, bed depth and temperature on ammonia removal were ascertained.

The experiments were conducted using river water containing 2 to 10 mg/ℓ of ammonia nitrogen which was passed through glass columns packed with pozzolana of 3 to 5 mm and 5 to 10 mm in diameter. Two series of experiments were pursued, one using two 60 mm diameter columns of 1500 mm and 870 mm height, and the other using two 80 mm diameter columns, one of 1330 mm height and the other 670 mm high. The influent was introduced into a buffer tank from which it was injected into the bottom of the columns where air was supplied by a compressor. Each filter was seeded by sludge from an extended aeration plant, the acclimation period at 12°C being approximately 15 days. Mathematical modeling of the results was accomplished using Monod's equation and attempts were made to measure the biomass in the filter using ATP analysis. In addition, the effects of temperature were incorporated into the model describing the results.

The conclusions reached by the authors were that the rate of nitrification is of zero order with regard to influent ammonia concentration, that the biomass decreases exponentially from the inlet at low flows, that ammonia removal at low flow decreases exponentially and becomes linear at high flows, and finally, that the maximum amount of ammonia that can be removed (ΔN) with the experimental apparatus is described by the equation:

$$\Delta N = 12 \frac{V}{Q} 1.07^{(t-10)}$$

where ΔN is in milligrams (mg), V is the volume of packing media in cubic meters (m^3), Q is the effluent flow in m^3/hr, and t is the temperature in degrees celsius.

In reaching these conclusions, it is important to note that the authors assumed that: 1) endogenous respiration is negligible, 2) even if the development of heterotrophic bacteria occurs, only the autotrophs remain on the media, 3) Monod's equation is applicable, 4) the ATP content is directly proportional to the biomass, and 5) the filters are completely seeded and at steady state.

Other observations of note were that nitrification was effective even at the lowest temperatures encountered (6°C) and that the ammonia removal doubled when the temperature increased from 6°C to 14°C.

A.2 Paper No. 5: "The Interrelationships Among Chemical Parameters in Rivers - Analyzing the Effect of Natural and Anthropogenic Sources," by J. S. Davis, J. Sobrist (Switzerland)

The studies reported were the results of an attempt to differentiate between the various sources of pollutants and to determine the relationships between the various inputs and the resulting conditions in the receiving water. The investigation was prompted by the large expenditures of money for pollution control and the need to determine whether or not commensurate social benefits were being attained and if the emphasis on removing a certain parameter was justified. The cost of obtaining the tremendous amount of data necessary to make this evaluation dictates the need for a model that will yield the desired information with a minimum amount of data.

The objectives of the study were to derive mathematical models describing the conditions of rivers under different types of loads, to determine the relative contributions of different sources to a river and to statistically analyze the data using linear correlations, factor analysis and regression curve analysis, thus minimizing the need for data.

The equations originally proposed by Manczak (Poland) were used as a base. These equations demonstrated that the relationship between concentration and flow would generally take three forms. Type I, for heavily polluted rivers, is primarily affected by the dilution of the wastewaters with increasing flow and is represented by an equation of the type:

$$C = \frac{A}{Q} + b$$

where C is the concentration, Q is the flow, and A and b are coefficients. Type II is representative of clean rivers, where the concentration increases with Q because of runoff contributions and/or the stirring up and transport of river sediments. The resulting concentration equations can be linear, second power or exponential with Q as follows:

$$C = b\, e^{qQ}$$

$$C = b + e^{1}Q^{2}$$

$$C = b + d^{1}Q$$

where q, e^1 and d^1 are constants. Type III, which is indicative of intermediately polluted rivers, is influenced by dilution of wastewaters at low flows and runoff effects at high flows. The resulting equation is:

$$C = \frac{A}{Q} + b + f(Q)$$

The authors assumed that the total loading could be divided into partial loads, each attributable to a particular source, either point sources or a number of diffusely distributed inputs. The latter were further divided into constant sources such as springs or groundwater, and those affected by runoff.

By analyzing the concentrations and/or loads by the previously mentioned statistical methods and using the river basin characteristics along with practical knowledge of the origin, behavior and fate of a particular parameter, major loading sources were determined. These sources included anthropogenic, background and runoff.

It was concluded that the statistical techniques described in the formal paper could estimate and differentiate the major loading source inputs to a river and thus give insight into where pollution control efforts should be concentrated and what their relative effects would be. It was claimed that the methods presented would: 1) reduce the complexity of data analysis, 2) group parameters on a "source" basis, 3) estimate the relative contribution of each source, and 4) develop criteria making possible comparison of various sampling stations and river systems.

A.3 Paper No. 8: "Mixing Model for Large Streams," by L. Somlyody (Hungary)

The paper described methodology for the mathematical modeling of wide rivers where the assumption of one-dimensional flow is not valid. The justification for the study lies in the fact that water quality parameters may be significantly affected by transverse mixing when the stream width becomes large and pollutants introduced may take up to 100 km or more before complete mixing is attained.

The objectives of the study were to develop a two-dimensional mathematical model using the turbulent diffusion equation describing the mixing of a conservative substance in two dimensions, curvilinear coordinates, the concept of mass flux constant lines and the continuity equation. The model developed could be used for locating influent and effluent structures, optimizing sampling locations and determining mixing zones. Furthermore, the mixing model serves as a base from which two-dimensional water quality models can be developed.

The author defined two kinds of models, process models and management models. While process models yield a better understanding of the phenomenon, the data base is large, the time of execution is long for real time simulation and practical application is questionable. On the other hand, the commonly used one-dimensional models may be over-simplified, and while data are available and real time computation is easy, the reliability of these "management" models may be questionable because of the many assumptions made.

Two features of the model developed were emphasized. One, the numerical solution, is not based on the transport equation, but on the concept of mass flux constant lines and on the equations of these lines. The water flow in a direction normal to stream lines is zero and lines can also be defined for which the transport of material in the normal direction is zero. These are called mass flux constant lines. Using these lines, not only will the concentration distribution and field be defined, but a geometrical picture of the process will be gained. The other feature of the method is that the model is coupled to hydraulic models and thus the coefficients influencing the phenomenon can be approximated by empirical formulae. A numerical solution, using the method of finite differences, was described as was a method for stability analysis.

The model was verified using both dye injections and ammonium ion concentrations observed in a stretch of the Danube River near Budapest. The agreement in both cases was reasonable although the mixing coefficients were adjusted in order to make the predicted concentrations more nearly fit the observed values.

Restrictions on the two-dimensional model were primarily associated with the detailed data requirements and the sensitivity of the model to the estimation of the mixing coefficients. Furthermore, it was noted that in the case of bank discharges, the spatial variation of the mixing coefficients must be taken into account. Again, this may not be possible in practice because of the lack of data. Finally, it was noted that three-dimensional flow conditions may also cause problems.

The author concluded that the model developed described the process adequately and should serve as the basis for further water quality modeling. It was stated that the model can readily be adapted to non-conservative substances and that deposition and resuspension should be taken into account.

B. Prepared Discussion

B.1 Paper No. 2

Karlgren (Sweden) pointed out that the nitrification phenomenon is of much more interest today than in the past, but for different reasons. He noted that fresh sewage will contribute some 11 gm/capita/day to the receiving water and of this, almost all will be nitrified in the receiving water. He also stated that nitrification in the wastewater treatment plant leads to difficulties in evaluating the performance of the plant because of the difficulties in evaluating BOD's affected by nitrifiers.

The NOD taken out in the treatment plant will reduce the load on the receiving water as noted in the Thames Estuary and in the Stockholm Archipelago. However, the effects of NOD on the receiving water must be balanced against increased corrosion noted in treatment plants with nitrification.

He contrasted the International Drinking Water Standards of 0.5 mg/ℓ with the high concentrations evident in the French waters and suggested that in lieu of the treatment proposed, the sources should be found and eliminated. In Sweden, if concentrations as high as indicated by the authors are found, either the sources are treated or another source of water is utilized as a supply.

Karlgren also discussed the problem of nitrates in the drinking water supplies and stated that Swedish tapwaters were exceeding the allowable 10 mg/ℓ. It was recently determined that the increase was caused by nitrification of ammonia in the distribution lines and thus the allowable concentration of ammonia in Swedish drinking water has been lowered.

He asked two questions of the authors. One was whether there was a need for special treatment to remove ammonia when other treatment processes would probably reduce the ammonia to acceptable values; in particular, if slow sand filtration was used, which would be probable in waters so highly polluted. The other question was why pH was not varied in the experiments when it is known that the optimum pH for nitrification is at pH 8-9, and not at pH 7 which was used.

B.2 Paper No. 5

Koppe (Germany) emphasized the importance of determining the relative contributions of sources. For example, one eutrophied reservoir in Germany has most of its phosphorus load originating from a tributary and thus the entire tributary flow is treated for phosphorus removal. Another German reservoir has the majority of its phosphorus contributed by wastewater treatment plants; thus all plants are being required to instigate phosphorus removal facilities.

A mass balance would be useful in particular for those sources that are well known and persistent. For example, boron is an important component of many detergents and can be useful in performing such a mass balance.

Two questions were posed. The first was whether or not the organics and ammonia should be differentiated between concentrations occurring in the winter and the summer inasmuch as differences would occur. The second question was whether or not the effects of the rate of flow changes with time should be taken into account. This is pertinent because the concentration of ions is greater at the beginning of a flood than at the end, even if the flow is the same in both instances.

B.3 Paper No. 8

Cederwall (Sweden) summarized the author's development of the model, noting that he had used the two-dimensional equation for the conservation of mass, the dependent variable being the time and depth averaged concentration and the independent variables being the flow field and the coefficient of lateral dispersion. He then discussed the use of the constant mass flux lines as delineated in the formal paper. Furthermore, he stated that two sets of inputs to the model were required, the first being the observed (measured) geometry, flow field and dispersion characteristics, and the second being the observed geometry, the surface profile computations and empirical evaluations of the two-dimensional flow field and dispersion characteristics.

His question was for the author to delineate the advantages of the constant mass-flux-line procedure over conventional modeling procedures from a physical, numerical and visualization standpoint with regards to point sources and distributed sources. In addition, he asked the author to define the characteristics of a "wide" river, since this is the basis for development of the model.

C. Floor Discussions

C.1 Paper No. 2

LeMotte (USA) noted that modeling of the process assumes that the reactor was plug flow in nature but no indication was given in the paper to justify this assumption. In addition, the kinetics of reactions occurring in biological films are heterogeneous. Therefore, in modeling such reactions, consideration must be given to the internal and external mass transfer resistances. Nothing in the paper indicated such consideration. Finally, the nitrification process is oxygen-dependent and if insufficient oxygen was present, the reaction could be oxygen-limited. In this regard, no indication was given in the paper that there was sufficient oxygen in the columns.

Sutton (USA) felt that the oxygen requirements must have been quite high in the experiments described inasmuch as over 40 mg/ℓ of oxygen would be required to satisfy the 10 mg/ℓ of ammonia that was sometimes present. Since no mention was made of the oxygenation system in the paper, a description of how these high levels of oxygen were supplied would be in order. Also, was any attempt made to measure the biofilm thickness?

Shabe (UK) noted that the influence of the surface area of the packing on the oxidation rate was not mentioned and only one filter varied the size of the media. Was this sufficient to ascertain the effect and what was concluded in this regard? Also, the author stated that the limit for ammonia in drinking waters in France is 0.5 mg/ℓ. What is the corresponding limit for nitrate? It should also be noted that the loading rate in Figure 4 of the paper is probably 3.1 m^3/m^2/hr instead of 31 m^3/m^2/hr.

Author's Reply - The oxygen levels reached 0.7 mg of air/mg of nitrogen and was adequate, although it was found that bacteria must be removed from the system. With regards to the pH, tests were performed that showed that a pH of 7 was optimal for the filters used. Finally, the allowable nitrate concentration in France is 50 mg/ℓ for drinking water.

C.2 Paper No. 5

Ellis (UK) reported studies on heavily polluted tributaries to the Thames show great variation, both spatially and temporally. The same pattern of loading does not occur over every storm event. Suspended solids loadings exemplify this variation inasmuch as differences of 1 to 2 orders of magnitude are observed. This would confirm the authors' contention that low correlations are associated with anthropogenic sources. Therefore, why not use a family of curves for various stages of flow and/or events? How could this be built into the model? Furthermore, for receiving waters dominated by stormwater runoff, a boundary condition of statistical significance is not easily identified, particularly when non-linear conditions exist. This generates a low or variable correlation coefficient and when dealing with occurrences of such a stochastic nature, factor analysis may be less suitable than other techniques such as Fourier Analysis, multi-dimensional scaling models, etc. Would the authors comment on this aspect?

Hahn (FRG) stated that discontinuities have been noted with respect to suspended solids and flow. The onset of sedimentation and onset of erosion results in these discontinuities. How does the model account for this? It may be dangerous to ascribe intensities to certain non-point sources that may not exist. Therefore, have you attempted to measure the effects of non-point sources from an entire drainage area and compared the results with your statistical model?

Perzez (France) reported that the method described is similar to French methods. However, the flow vs. parameter of distribution is bi-modal and not statistically significant in their studies. The French investigators have also found that one year of observation is not sufficient.

Manczak (Poland) observed that temperature must be accounted for in the analysis. Furthermore, it has been shown in Polish studies that at least 50 observations are required for a good test.

Author's Reply - Temperature changes in Swiss rivers are not too great; therefore, it is thought that this is not a factor. Studies to demonstrate this are planned, however. The effects of discontinuities caused by increasing or decreasing flows should be ameliorated because of the weekly sampling; however, studies in this regard are also planned. Thus far, only short term effects have been analyzed.

C.3 Paper No. 8

Author's Reply - The definition of wide streams and where the proposed model is applicable may be determined by defining whether or not the one-dimensional model is valid. Practically, a stream over 100 m in width is a "wide" stream and two-dimensional analysis must be used. The advantages of the model include a more accurate description of the phenomenon involved and its adaptability to changes in water quality.

D. Other Observations and Comments

The general theme of the session appeared to be of considerable interest; however, some disappointment was expressed by several participants in regards to Paper No. 2, which was of a treatment nature rather than as the title implies. While the last paper (No. 8) was highly mathematical in nature, the lack of floor discussion indicated that either the participants were not well versed in the subject matter, the preprints were not read, or the preprints were not available. It should be noted that the work was outstanding and the author's presentation of sophisticated mathematics in general terms was laudable.

IV. CRITIQUE OF SESSION

With the exceptions noted in III-D, the session was well received and of general interest to the audience, much discussion on the water quality aspects of the papers being promoted. Some of the papers demonstrated a lack of knowledge of similar work being pursued elsewhere, e.g., the submerged nitrification investigations, and the statistical analysis of water quality and flow. It is believed that the nitrification studies in particular could have been improved if information obtainable from other countries was used. On the other hand, this demonstrates the need for international conferences.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Inasmuch as the papers contained subject material of such a varied nature, they must be discussed separately.

While the objectives of the nitrification investigation in France are not of value to the U.S., the process may be of interest. The use of submerged filters possibly has the advantage of avoiding "washout" of nitrifiers in conventional processes. Thus, the kinetics derived by the authors could be of value in the U.S. practice. The temperature relationship is of particular significance as is the observation that nitrification in the submerged filter was effective at low temperatures (6°C). Before using the conclusions, however, some of the questions posed by the discussers should be answered. For example, was the oxygen supply a limiting factor and did the reactor demonstrate plug flow?

The statistical attempt to differentiate between various sources is particularly significant in the U.S. and should be evaluated for utilization and modification for U.S. conditions. For example, if treatment plant contributions of phosphorus constitute only 10 percent of a phosphorus load causing problems, its removal at the treatment plants would not be cost-effective. Obviously, the converse is true. The problem of when to require nutrient removal has been magnified by the GAO report of last year and the approach described may be of value in this regard.

Finally, the modeling efforts of Somlyody are worthy of note from the theoretical standpoint inasmuch as some two-dimensional models have been required to satisfy Section 316(a) studies. However, from the practical standpoint, the data base required for this sophisticated modeling will probably preclude its use in the U.S. in the near term. In addition, there is still considerable question as to the delineation of the mixing coefficients, their determination being empirical in nature. Also, the results of the sophistication over the one-dimensional model as described by the author do not seem to justify the effort involved as demonstrated by the model verification.

I. SESSION

A. Day: Monday, June 12, 1978
Hall: C
Time: 2:00 to 4:30 pm

B. Theme of Session: Treatment of Sludges

II. REVIEWER

A. Name: Clifford W. Randall

B. Position and Affiliation: Professor of Sanitary Engineering and
Director, Occoquan Monitoring Program
Department of Civil Engineering
Virginia Polytechnic Institute and
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Blacksburg, VA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 3: "A Novel Method for Assessing the Thickenability of Sludges," by M. J. D. White, C. F. Lockyear (UK)

The authors presented a low-speed, laboratory-scale centrifugation test which they propose can be used to assess the thickenability of sludges and provide guidelines for thickener design. Their objective was to develop a rapid, easily assessed procedure for characterizing the thickenability of compressible sludges that would require small volumes of sludge and could be used instead of pilot-scale column testing. The method developed requires less than 1 ℓ of sludge and testing can be completed in a few hours.

The theoretical approach is that the high compressive forces that occur in deep sludge blankets in full-scale thickeners can be applied to a sludge sample in the laboratory by using centrifugal force. Since the rate of thickening and the final solids concentration achieved for a compressible sludge are largely determined by these forces, it was postulated that the method would provide a realistic assessment. It was proposed that realistic scale-up of compressive forces and time of thickening could be accomplished using relationships based on the ratio of the initial suspension heights in the full-scale thickener, H, and the centrifuge tube, h.

The centrifuge used was a modified commercial one that consisted of a vertically mounted 22 mm thick aluminum disc, with a diameter of 500 mm, rotated by a motor and a variable speed gearbox. Two tubes containing sludge were fixed to the disc, which was illuminated by a stroboscope triggered by the tubes so that the interface between sludge and supernatant liquor in either tube could be observed independently. Tubes of varying length and diameter could be used. The disc was surrounded by a safety cabinet with a viewing port, in which a clock was mounted. Relative centrifugal forces of 10-100 g were used. Centrifuge start-up time was on the order of 5 sec and the relative centrifugal force (RCF) along the length of the tubes varies by about 20 percent for interface heights of 30 to 80 mm.

The investigators used a primary sludge and a waste activated sludge to assess the reproducibility of the centrifuge technique and to evaluate the effect of centrifuge tube diameter on the results obtained. The method was then used to characterize chemical, biological, and primary sludges from a variety of sources. Changes of solids concentrations in the centrifuge tubes were determined and compared with results obtained in 1-m and 6-m columns. Next, a series of tests were performed wherein the impact of adding portions of alum sludge, activated sludge and trickling filter (humus) sludge to primary sludge was evaluated. Finally, the authors developed a formula which they propose can be used to calculate the final solids concentration that can be achieved in a gravity thickener using data from centrifuge experiments.

The reproducibility of the centrifuge technique was found to be very good for both primary and waste activated sludges. Using table diameters of 7, 14, 22, 28, and 35 mm, it was concluded that wall effects were small and would not seriously affect the method. Characterization of the various sludges produced reasonable and logical results and apparently made it possible to determine whether sludge-blanket depth is likely to be an important factor in thickening of the sludge in question. The calculated concentration gradient in the centrifuge tubes compared very well with those experimentally determined and also with those found in pilot-scale thickening of the same sludge. The impact of adding portions of alum, activated and humus sludges to primary sludge, as predicted by the centrifuge test, was consistent with results that have been observed at full-scale installations and are well known in the literature.

It was shown that for the same compressive force, the centrifuge test will accurately predict the ultimate concentration of sludge that can be obtained in a gravity thickener. The equation developed to describe both centrifuge and gravity thickening data was fairly complex and not to the satisfaction of the authors. From analysis they concluded that it did not apply universally and, therefore, it is not possible to predict the performance of a full-scale gravity thickener from centrifuge data alone.

A.2 Paper No. 6: "The Use of Pulped Newsprint as a Conditioning Aid in the Vacuum Filtration of a Municipal Sludge," by H. W. Campbell, R. W. Kuzyk, G. R. Robertson (Canada)

The major disadvantage of the utilization of incineration as a method of sludge disposal is generally considered to be the inability of current technology to produce a sludge cake with a high enough caloric value to support its own combustion. In fact, common sludge dewatering technology requires the addition of inorganic materials such as lime, alum and ferric chloride to the sludge for conditioning purposes prior to dewatering and the addition greatly reduces the caloric value of the sludge-conditioning chemical mixture. The authors of this paper evaluated the use of cationic organic polymers plus newsprint pulp as a method of conditioning sludge for vacuum filtration, as an alternative to the addition of ferric chloride ($FeCl_3$) and lime. The study was conducted at the Greenway Pollution Control Center, London, Ontario, which is a conventional activated sludge plant with a design capacity of 1.4 m^3/s, and equipped with dissolved air flotation, vacuum filtration and multiple hearth incineration for sludge handling purposes. The sludge used was a 1:1 mixture of raw primary and waste activated sludge from this plant.

In the first phase, bench scale experiments utilizing Buchner funnel. capillary suction time and filter leaf testing were conducted. The purpose was to establish basic relationships between various polymer/pulp/sludge mixtures and the dewaterability of the conditioned sample. Next pilot, and then full-scale, coil spring vacuum filters were operated to determine scale-up relationships, evaluate the importance of operating variables, and document operating problems.

The newsprint was pulped with water and added to the sludge in the form of a slurry until the desired percentage was reached in all experiments. Following leaf testing or vacuum filtration, the filter cake was further dewatered by mechanical pressure prior to incineration. A V-type continuous press (Rietz Press Model No. RVP-36) was used for full-scale operation. During bench-scale and pilot testing, pulp dosages of 20 to 71 percent were used and three cationic polymers were evaluated. For full-scale operation, pulp dosages of 30 and 35 percent and a polymer dose of 4 kg/metric ton produced the most consistent results. This was compared to lime plus $FeCl_3$ conditioning wherein the applied dosages were 41 percent and 8.1 percent, respectively.

The most important findings of the study are as follows: 1) polymer-pulp addition did not significantly change the caloric value of the sludge whereas lime-$FeCl_3$ conditioning decreased it by 37 percent; 2) the polymer-pulp conditioned the sludge better than lime-$FeCl_3$ (in full-scale operation, the resulting filter cake solids were the same but the filter yield was 39 percent greater and the filtrate suspended solids concentration was only 2000 mg/ℓ as compared to 8000 mg/ℓ for the lime-$FeCl_3$ sludge); 3) bench-scale and pilot experimentation showed that the cake solids obtained after pressing was a function of the percentage of pulp added rather than the polymer dosage or the filter cake solids concentration; 4) pilot testing accurately predicted full-scale results but filter area predicted by leaf test results needs to be increased by a factor of 1.10 to 1.15 when scaling-up; 5) the Rietz press following vacuum filtration was unsatisfactory because of inconsistent performance. The resulting cake solids were extremely sensitive to variations in the filter cake and a minimum pulp addition of 50 percent was required to achieve an autogenous cake.

It was concluded by the authors that polymer-pulp addition was a viable alternative to lime and ferric chloride. Because of the higher caloric value of the resulting cake and the significant reduction in filtrate solids, yearly operation and maintenance savings of $240,000 were projected. A newsprint cost of $38.50 per metric ton was assumed. The estimated capital cost for the paper pulpers, pumps and polymer addition system was estimated to be $427,500 for the 1.4 m^3/s plant. Therefore, a pay-back time of approximately 2 yr was projected.

The speaker stated that, as a result of their investigation, the City of London, Ontario, has purchased and installed newsprint pulpers at the treatment plant to be used with the vacuum filters and operation is expected to begin in July 1978.

A.3 Paper No. 9: "Properties and Treatment of Lime-Algae Sludge," by A. Cohen, E. Idelovitch (Israel)

The treatment of wastewater from the Southern Tel Aviv Metropolitan area, under the Dan Region Project, consists of biological treatment in oxidation ponds followed by two-stage high lime-magnesium chemical treatment. The chemical treatment process consists of, first, a sludge blanket reactor-clarifier, wherein high doses of lime and small doses of magnesium chloride are mixed with the oxidation pond effluent to raise the pH to 11.5 and promote flocculation. The flocculated sludge blanket is used to achieve clarification, and this is followed by shallow (0.9 m) polishing recarbonation ponds. Because the wastewater has a relatively high alkalinity (350 to 400 mg/ℓ as $CaCO_3$), lime dosages of 600 to 700 mg/ℓ must be used to raise the pH to the desired level. The magnesium chloride is added to enhance flocculation and concentrations of 40 to 50 mg/ℓ are maintained in the reactor. Thus, large quantities of sludge, which must be dewatered and disposed of, are produced in the reactor-clarifier, and, to a lesser degree, in the polishing-recarbonation ponds. The sludge consists primarily of lime and algae.

This paper, presented by Idelovitch, describes the results of a large pilot plant investigation wherein the properties of lime-algae sludge were determined, sludge yields for the chemical treatment process were measured, sludge was dewatered on sand beds, and preliminary attempts at resource recovery from the sludge were made. The data were separated to provide comparison of summer and winter performance. The primary emphasis of the study was on the lime-algae, or first-stage, sludge from the reactor-clarifier rather than the recarbonation, or second-stage sludge from the shallow polishing ponds. A two-week detention period and atmospheric CO_2 were used to accomplish recarbonation in the latter unit. This resulted in a pH drop from 11.5 to 9.5-10 with some sludge generation.

The sludge blanket clarifier-reactor reduced a median influent organic suspended solids (algae) concentration of 130 mg/ℓ to an effluent median of 30 mg/ℓ during summer operation (20-30°C). The winter (10-20°C) concentrations were 225 mg/ℓ and 75 mg/ℓ, respectively. This was accomplished at an average flow of 15 m^3/hr, which corresponds to an overflow rate of 1.5 m^3/m^2/hr. The resulting summer sludge concentration varied between 5 percent and 23 percent by weight whereas the winter sludge varied between 3 percent and 14 percent. The typical operating concentration was between 7 and 13 percent.

The authors reported a reverse correlation between influent suspended solids and sludge concentration. Clearly, the higher the algae content the less concentrated the resulting sludge. The specific gravity of the sludge varied between 1.02 and 1.08 g/cm^3, and it was possible to establish a correlation between specific gravity and sludge solids concentration. It was noted that when the pH was above 11, the removed sludge was free of bad odors, but such odors were emitted when the pH was below 11.

The total sludge yield was found to be approximately the same during both summer and winter operation (1.20 and 1.25 kg dry matter/m^3 of treated effluent), but the distribution between the first and second stage was very different. The percentage of the sludge collected in the clarifier-reactor increased from 60 percent in the summer to 87.5 percent in the winter. The average ratio between measured sludge yield in the clarifier reactor and hydrated lime dose was 1.33.

Analysis showed that the sludge consisted of 70 percent $CaCO_3$, 16 percent organics, 7.5 percent $Mg(OH)_2$, 4.5 percent $Ca_5OH(PO_4)_3$, and 1.5 percent SiO_2. The remaining 0.5 percent included heavy metals but it was concluded that the concentrations were too low to cause environmental concern.

Wet sludge with a solids concentration of 9 percent was applied in depths of 25 to 30 cm to the sand beds. The sludge dewatered to solids concentrations of 30-35 percent in about 3 days during the summer and about 7 days during October. The speaker reported, however, that sand beds had since been abandoned for centrifugation to simplify operator work.

The only resource recovery reported was the dissolution of magnesium with CO_2. It was found that such treatment resulted in recovery of 30 to 70 percent of the magnesium, considerably improved the dewatering properties of the remaining sludge, and greatly increased the amount of organic matter that could be recovered by centrifugation.

B. Prepared Discussion

B.1 Paper No. 3

Monteau (France) (speaking in place of Ben Aim) concluded that the test was a very positive advance in the search for a simple, realistic test that could be used to design thickeners. He made the point that current technology relies on empirical results from batch thickeners that must be the same height as the prototype, yet this is unsatisfactory because of the problem of wall effects. He stated that because of the wall effects problem, the recently issued European standard procedures document had omitted any test for thickener design. Monteau noted that the lack of significant wall effects and good probability reported by the authors was very encouraging and thought the authors should have analyzed centrifuge work by Vesilind and Martinson to emphasize the uniqueness of their method. The critical comment was made that the centrifuge test probably simulated filtration more than gravity thickening because it accelerated the flow of liquid through the sludge. He also thought a comparison between the proposed test and the standard one for determination of the coefficient of compressibility should be made.

B.2 Paper No. 6

Dick (USA) noted that the use of newsprint pulp for sludge conditioning appears to be inherently attractive because it would seemingly add thermal value to the sludge while improving the dewaterability. In contrast, the use of inorganic chemicals is detrimental to incineration because they: 1) contain moisture which must be evaporated, thus increasing fuel requirements; 2) increase mass of ash remaining; 3) increase heat loss to ash; and 4) may result in loss of energy through endothermic reactions. He stated that the authors' results were disappointing, however, because, in full-scale tests, their newsprint pulp additions added had more water associated with it than could be evaporated by the thermal value of the newsprint. Dick suggested that the elimination of pulp and use of polymer alone might have given better overall performance or that the addition of "dry" newsprint to polymer-dewatered sludge might have improved thermal performance. He asked why the researchers did not use massive dosages of pulp without polymers inasmuch as other researchers have obtained favorable results in this way and noted that Malina (1970), using pulp dosages twice as high to condition waste activated sludge, eliminated polymers and yet achieved specific resistance values lower than those reported by the authors. Since polymer costs far exceeded those for pulp during the reported study, this alternative would appear to be attractive. He questioned whether the authors had truly identified the optimum dosages of pulp and polymer for the experimental sludge and noted that the "filter performance factor" used by the authors did not seem to be a satisfactory way of judging alternative conditioning techniques since it assumed that cake solids concentration, yield and solids recovery are equally important factors in dewatering, and because the factor is not related at all to the thermal value of the conditioned sludge. He thought separate analysis of variables, such as relating the degree of dewatering achieved by alternate dosages to combustion costs, would have been more valuable. Dick also stated it would be useful to know how pulp affected the basic physical properties of sludge when accomplishing an improvement in dewaterability, and suggested this could be elucidated by conducting experiments at varying pressures to determine effects on sludge compressibility. He commented that the authors' conclusion on the need of a scale-up factor from leaf test to full scale may be incorrect since a greater pressure differential was used for the bench tests than for full scale tests. Finally, he questioned why the authors had an activated sludge with dewatering properties better than the primary sludge and, therefore, whether they thought their results would transfer to treatment plants having more typical sludges.

B.3 Paper No. 9

Bosman (South Africa) noted that the improvement of lime treatment by the addition of magnesium and the existence of a threshold value of 40-50 mg/ℓ magnesium for good clarification, as reported by the authors, has been confirmed at other plants (Best, 1977). She questioned whether the authors had considered the addition of electrolytes or polyelectrolytes other than magnesium and wondered if polyelectrolytes could have been used to increase the sludge concentration when the organic content of the suspended solids was high and if there was a rational explanation for the higher organic content of the lime-algae sludge during winter rather than summer. Also, Bosman questioned why the $CaCO_3$ content of the sludge was greater during winter than summer, and asked if it was caused by faster rates of reaction at higher temperatures resulting in formation of more, but smaller, nuclei and hence slower settling. She stated that the inclusion of settling curves in the text would have clarified this point and asked if it was not possible to settle a sample of second-stage sludge under more controlled conditions so that sand contamination could be avoided. She also asked whether further work on treatment of the sludge for resource recovery had been performed.

C. Floor Discussions

C.1 Paper No. 3

Dick (USA) stated that the centrifuge test of White and Lockyear seems to be a valuable means of characterizing the consolidation properties of sludges and felt that this information could be used for quantitative comparisons between sludges and to provide information on the maximum achievable suspended solids concentration which would be expected under various conditions of compression. He recommends caution, however, before using centrifuge results "to provide guidelines for design" and "to predict the concentrations of sludge withdrawn," as suggested by the authors because of two complications which may occur. Dick stated that the authors' approach assumes that the entire weight of the sludge solids is effective in compression of solids at the bottom of a gravity thickener when, in reality, this occurs only after all sedimentation has been completed because, until then, fluid drag forces are partially supporting the solids. He also noted that the total compression circumstance does not occur even after long periods of sedimentation and, thus, such a design would not be economically feasible. As support, he quoted the results of Shin and Dick (1975) wherein they found, after 2 hr of batch sedimentation of a 100 g/ℓ suspension, only 25 percent of the solids were actually being supported by the solid phase of the sludge whereas 75 percent were still being supported by fluid forces and concluded that these fluid forces would probably prevent consistent agreement between batch thickeners and centrifuge test prediction.

As a second complication, which could cause lack of agreement between centrifuge prediction and continuous thickening, Dick commented that the performance of a continuous thickener is not ordinarily limited by the thickening behavior of the sludge at the final concentration at which it is drawn from the tank, but by the layer with the lowest capacity for transmitting solids downward under the existing operating conditions. Sludge at the concentration of this layer, rather than the maximum possible concentration, would control thickener performance. He concluded, therefore, that while the authors' technique would predict the maximum possible thickened sludge concentration, it would not ordinarily predict performance of continuous thickening.

Author's Reply - White, in reply to Monteau, stated that they (the authors) had referred to Vesilind's paper wherein he used a stroboscope to predict the concentration of sludge in a centrifuge. Thus, the authors' proposed test was unique because it compared results between a centrifuge tube and a batch gravity thickener; moreover, low centrifuge speeds, thus low gravity accelerations, were used. The authors did compare centrifuge tube results with those obtained in both a 1-m laboratory and a 6-m pilot-scale batch gravity thickener. They tried to correlate compressibility in the centrifuge tube to that obtained during specific resistance testing. A correlation was achieved but it was not a very good one. Nevertheless, they believe the ease of the centrifuge test compared to specific resistance testing for compressibility is so great, it is a preferable method. White stated that Monteau was correct in concluding that the phenomenon observed in the centrifuge tube was closer to filtration than sedimentation.

In reply to Dick, White commented that the authors had demonstrated a correlation between concentration changes in batch thickeners with applied load. While the concentrations reported in the paper were final concentrations, they had looked at intermediate concentrations and had found that they could predict them too. White stated that, while theoretically it would appear that hydrodynamic forces would prevent correct prediction, in fact, they did not. He concluded that, apparently, enough of the load was applied to make negligence of hydrodynamic forces insignificant.

White noted that since the writing of the paper, the final modeling equation given in it has been discarded and a new one formulated. He did not present the new one, however, because he feels it is still too complicated and the search for a simpler one is continuing. To sum up their findings, he emphasized that they can convert the time scale observed with the centrifuge to that observed with a batch gravity thickener. The conversion requires application of a factor, however, which depends on the difference between the initial and final sludge concentrations observed and the geometry of the thickener. He concluded that the proposed test would predict the effects of system geometry.

C.2 Paper No. 6

Dean (Denmark) stated that knowing the calorific value of a sludge was not sufficient information for incineration. The ratio of the fuel value of the sludge to the water content that must be evaporated must also be known. He remarked that the idea of using newsprint pulp as a filter aid is very old but that newsprint pulp is too valuable for this use. To justify use of pulp, dewatering properties must be greatly improved, otherwise a material with a much higher calorific value, such as coal, should be used for conditioning prior to incineration. He referred to work by Farrell of EPA, Cincinnati, which was published, he believed, by Hathaway and Olexey. He thought the paper could have been improved by separation of the two pulp addition effects, i.e., improvement of sludge fuel value and reduction of water content.

Author's Reply - In answer to Dick's questions, Campbell stated that the authors did not pretend that their dosages for pulp and polymer were optimum. They were simply looking for a system that would work and to document whether significant problems would occur. He agreed that the use of polymer alone would be preferable if similar dewatering results could be maintained but stated that many polymers have been investigated by the City of London and consistent results have never been achieved. He agreed that higher pulp dosages may be preferable and/or that adding it in a drier form might be better but such experiments have not been tried and he admitted that the performance factor they used is relatively crude but thought it was adequate for the preliminary work they did. Campbell agreed that the inclusion of the sludge calorific value in it would improve it. He stated they did not investigate how pulp works to improve dewatering and they have no speculation. He agreed that the pressure differential between bench-scale and full-scale experiments may have been responsible for the scale-up factor reported but commented that he would be reluctant to scale-up from leaf tests anyway. He noted that the activated sludge had better dewatering properties than the primary sludge because it had already been conditioned and thickened by polymer and dissolved air flotation. Campbell was not sure about transferability to other sludges but could foresee no major problems. In reply to Dean, he stated that the cost of newsprint pulp had been included in their economic analysis and that the City of London had recently contracted with a newsprint supplier at the fixed rate of $42/metric ton, which was only $2/metric ton higher than the value used during analysis.

C.3 Paper No. 9

Tesarik (Czechoslovakia) gave a lengthy discussion of problems associated with solids contact clarifiers that was not very pertinent to the paper presented. He stated that rake movement can cause mean velocity gradients which may seriously affect performance of such a clarifier. He showed slides and data of experiments he had performed which illustrated that an optimum mean velocity gradient ranged between 40 and 50 sec^{-1}.

Shuval (Israel) commented that a possible sludge recovery practice would be utilization of the organic fraction. The authors' process is suitable for this because high lime treatment virtually eliminates pathogens such as bacteria and viruses. This has been demonstrated for the described process by Shuval. However, lime also precipitates metals which would be in the sludge and this is a disadvantage.

Author's Reply - Idelovitch, in replying to Bosman, pointed out that their studies did not investigate magnesium addition as a separate variable. He noted that the presence of magnesium had a strong adverse effect on sludge dewatering but it was already present in the wastewater in a concentration of 30 mg/ℓ and they were able to use it as an effective coagulant aid by increasing the concentration to 40-50 mg/ℓ. He believed this was the most economical approach and that any polymer addition should be to the sludge to improve dewatering, not to the wastewater to aid clarification. He stated that the sludge organic content was higher in winter than in summer because the oxidation ponds were not as effective for organic removal because of lower temperatures, but the algae concentration did not change significantly. Idelovitch observed that the purpose of the polishing ponds was to use atmospheric CO_2 to accomplish first stage recarbonation, i.e., conversion of hydroxides to carbonates, and that a two-week detention time would accomplish this with a pH drop from 11.5 to 9.5-10. He did not characterize second stage sludge because of time limitations and because sand blew into the pond. He concentrated on first stage sludge because it has to be removed whereas second stage sludge doesn't. With respect to resource recovery, he noted that plant operators had insisted on the replacement of sand bed dewatering with centrifugation. Centrifugation satisfactorily dewaters the sludge only if pretreatment is used but recovery of magnesium from the supernatant is enhanced by the convenient separation of solids and liquid. He plans to practice magnesium recovery plus phosphate and organics recovery, but will probably not go to lime recovery because of energy considerations.

D. Other Observations and Comments

D.1 Paper No. 3

Private conversation with White elicited the following comments and information. He stated that while he was aware that theoretical considerations would indicate that hydrodynamic forces would prevent agreement between centrifuge tube results and batch gravity thickeners, in fact, they had been able to demonstrate that such agreement did exist. As an engineer he does not feel that the failure of theory to accurately describe a process should prevent utilization of an empirically proven procedure. The new formula they have developed in place of equation (11) in the paper is as follows:

$$C/C_\infty = \left(\frac{C_o}{C_\infty}\right)^{\mu/\mu+t+t_i}$$

where;

$$\mu = f(a) + f(C_o) = K_1 a^m + K_2 C_o^n$$

All symbols are as identified in his paper. They are still seeking a simpler equation, however.

The reviewer feels that White and Lockyear have developed a very promising test. The correlation between centrifuge tube and batch thickener appears to be remarkably good and the procedure is certainly far simpler than the alternatives. Although both Dick and White state that fluid forces should theoretically prevent the observed agreement, the reviewer is not convinced that this should be so. They have apparently assumed that hydrodynamic effects in the centrifuge tube are theoretically negligible because of rapid concentration of the sludge. Since low centrifugal accelerations were used, this was not necessarily the case and it is conceivable that fluid forces in the tube were significantly supporting the solids to nearly the same degree that occurs in a batch thickener in spite of the differences in particle acceleration. This should be investigated more thoroughly before wide acceptance of the test, however.

D.2 Paper No. 6

Although the investigations of Campbell *et al.* resulted in the adoption by the City of London, Ontario, of pulped newsprint addition for sludge conditioning and subsequent incineration purposes, the criticisms of the procedure and the investigation appear to be very valid. Clearly incineration of sludge plus pulped newsprint is favorable compared to incineration of sludge plus lime and ferric chloride but it seems very likely that better techniques or, at least, a significant improvement in the suggested procedure could be accomplished by well-designed additional investigation. Reduction of the water content of the added pulp would appear to be an obvious place to start but numerous other changes, as suggested by the discussers, could also be made.

D.3 Paper No. 9

This paper was primarily descriptive but was well done in that the most significant aspects were addressed. The treatment scheme used appears to be a rather ingenious system that could be adapted to many areas around the world.

IV. CRITIQUE OF SESSION

The reception of these papers seemed to have been somewhat mixed. The response to Paper No. 3 was relatively good although some caution was evident. Paper No. 6 appeared to be received with a considerable amount of skepticism, however, probably because the idea was not new and original and because the investigation did not appear to be consistently planned or performed. The reception accorded Paper No. 9

appeared to be somewhat indifferent. Apparently there was little initial interest in the characteristics of lime-algae sludge among the audience. The reviewer feels the degree of interest will change in the very near future, however, and that the presentation was timely and the research well done.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Papers No. 3 and 9 should be of considerable interest to American researchers. A convenient, rapid test for sludge thickening characterization and unit design is of considerable interest to anyone who has determined compressibility by specific resistance tests or used pilot columns for design purposes. Further development of the promising technique proposed would appear to be in order. Interest in Paper No. 9 should be great, not so much because of the main thrust of the paper which was to characterize lime-algae sludge, but because of the total treatment system described. Recent relaxation of standards in the USA has stimulated new interest in waste stabilization ponds and this paper addresses the main reservation most designers have for the process, although it was not the main thrust of the research. The reported results show that a waste stabilization pond can be upgraded to the point that a high quality effluent can be produced by the addition of wellknown techniques. A fear of many designers has been that, while a waste stabilization pond may be an acceptable solution today, future pressures for an upgraded effluent may result in abandonment of the pond and construction of an entirely new facility. This can be difficult to explain to a town council when the pond has been in operation for only a short time. Adoption of the total process in operation in Israel would appear to be appropriate in many parts of the country although investigations of alternative coagulant aids would probably be desirable in many instances.

REFERENCES

1. Shin, B. S. and R. I. Dick, "Effect of Permeability and Compressibility of Flocculent Suspension on Thickening," *Progress in Water Technology*, 7, 2, 137-148 (1975).

2. Malina, J. F., Jr., "Sludge Filtration and Sludge Conditioning," in *Water Quality Improvement by Physical and Chemical Processes*, E. F. Gloyna and W. W. Eckenfelder, Jr. [eds.], University of Texas Press, Austin, Texas, 370-387 (1970).

3. Best, R. and N. Banks, "Advanced Wastewater Treatment in the United Kingdom: The Doe Project," International Conference on Advanced Treatment and Reclamation of Wastewater, Johannesburg (June 1977).

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: A
Time: 9:00 am to 12:30 pm

B. Theme of Session: Deep-Bed Filtration

II. REVIEWER

A. Name: Walter J. Weber, Jr.

B. Position and Affiliation: Professor of Environmental and
Water Resources Engineering and
Chairman of the Water Resources Program
The University of Michigan
Ann Arbor, MI

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 10: "A New Concept of Filterability," by K. J. Ives (UK)

The specific thrust of Ives' paper relates to measurement of "filterability." The author notes that, although many of the properties of suspensions to be filtered and many of the properties of filter grains can be determined, there is no satisfactory single measure of whether a suspension can be filtered through granular media. Ives proposes a "filterability number," the ratio of the response (head loss and filtrate quality) of an experimental filter to the amount of suspension applied per unit area of the filter. He further describes a prototype experimental filter for making such measurements.

Results of laboratory experiments using the filterability apparatus on kaolin and quartzite suspensions subjected to various doses of alum and anionic polyelectrolytes and a range of velocity gradients and flocculation times were presented. Other verification experiments using various sequences of pretreatments (sedimentation and flocculation), various filter media (sand, anthracite, glass beads), and filtration rates (5 to 15 m/hr) were described.

The essential conclusions of the paper may be summarized as follows: 1) the filterability number is a simple dimensionless concept; 2) the apparatus is compact and portable, simple in operation, requiring no electric power and requiring about 1 ℓ of sample; 3) the apparatus is suitable for preliminary tests before pilot plant studies, suitable for operational control on water works or sewage treatment works, and suitable for student teaching.

A.2 Paper No. 13: "The Role of Retained Particles in Deep Bed Filtration," by C. R. O'Melia, W. Ali (USA)

The paper by O'Melia and Ali presents a conceptual model for interpretation of particle size and "ripening" effects in deep-bed filters. The authors note that traditional filtration theory would indicate that submicron particles are effectively transported in packed beds to the surfaces of the filter media by diffusion; further, that particles of a few microns in size or larger are effectively transported by settling and fluid flow, or interception. However, particles around one micron in size have a minimum contact opportunity, being too small for settling and interception and too large for diffusion. The authors also note that, in the past, there have been experiments in which similar filters treating similar mass concentrations of material produced different results, and that these observed differences have been ascribed usually to differences in the solution or surface chemistry of the system. Conversely, the authors offer a physical explanation. The thrust of their argument is that particles deposited in the bed function just as much as filter media, as does the media originally installed in the clean filter bed. This conclusion is predicated in substantial measure on the hypothesis of dendrite formation within the filter during the course of filtration.

The authors then proceed to fit a relatively simple operational model - which they indicate is totally empirical - to several sets of filtration data to calibrate model coefficients, and test this calibrated model on other data for purposes of verification. This done, they then examine the sensitivity of the model to various parameters, such as filter media size and suspension particle size.

The principal and most general conclusion arrived at by the authors is that in many, and probably most, packed bed filters used in water and wastewater filtration, the actual filter media operative during most of the filter run is not the sand or coal installed by the designer, but the particles present in the water applied to the bed and retained in the filter. Stated in another way, the actual filter media is formed from particles present in the original water and altered during the pretreatment process. Hence, the design of a filter and selection of filter media really involves the design of pretreatment processes, and depends on the concentration and size of the original particles, the effectiveness of pretreatment chemistry in destabilizing these particles, and the effectiveness of pretreatment physics; that is, settling, flocculation and altering the concentrations and size of the particles to be filtered.

A.3 Paper No. 16: "Particulates and Trace Pollutant Removal by Depth Filtration," M. C. Kavanaugh, M. Chung, E. A. Pearson (USA), G. Toregas (Greece)

The paper by Kavanaugh *et al.* proposes a conceptual and methodological approach to the selection of solids-liquid separation processes with respect to the removal of trace-pollutant materials associated in one form or another with particulates. The authors state that the selection and evaluation of solids-liquid separation processes has traditionally been based upon collective parameters such as turbidity or suspended solids, but that a number of techniques are now available which permit identification of details about the particulate matter of concern; specifically, which particles in a heterogeneous suspension need to be removed to satisfy a particular standard.

Several sets of particle size distributions for different suspensions are presented in the paper; the data are represented in terms of the size of the particle versus the number of particles per size-class interval. The authors state that, to a reasonable approximation, each distribution can be mathematically described by a simple power law, characterized by two parameters, namely, the slope of the curve and an empirical constant. They indicate that the important aspect of this is that frequency distributions can be developed for particle number, surface area and volume. They give an example to show that, for one particular distribution, most of the number of particles are in the small size fraction while almost all of the volume, or mass, is in the larger size fraction and the surface area is distributed equally among all size classes. The authors indicate that, depending upon the water quality parameter of concern, and its nature and degree of association with particulates of various size, such distributions can be used to select an appropriate solids-liquid separation process. T[illegible] ive an example of the selection of one of several filtration alternat[illegible] based on a particular suspension and effluent objective.

The paper concludes that particle size distribution information, in particular the shape of the distribution, combined with data on the distribution of the pollutant between the dissolved and the particulate phase, permits determination of which size fractions must be removed, and therefore facilitates selection of appropriate unit processes.

A.4 Paper No. 19: "Removal of Residual Phosphorus and Suspended Solids by Contact Filtration," by L. Pelloni (Switzerland)

The paper by Pelloni describes the results of experiments with what the author indicates is the most commonly employed technique for phosphorus removal from wastewaters in Switzerland; namely, chemical addition after primary clarification and contact filtration after final clarification. He presents comparisons with other alternative arrangements, and indicates the choice of this particular technique was made largely on the basis of economics.

Pelloni discusses the effects of several process variables and describes a laboratory test method for pre-optimization of these variables. He presents pilot plant data which indicate that, in addition to reducing phosphorus levels to 0.1 mg P/ℓ, the process scheme also achieves approximately 90 percent removal of total suspended solids. A mathematical model for description of retention dynamics in contact filtration is presented and its application - potentially in conjunction with a process computer - to adapt backwashing schedules with the state of loading of filters is discussed.

B. Prepared Discussion

B.1 Paper No. 10

Hallen (Sweden) emphasized that it may be dangerous to include many parameters in one filterability number. He indicated that in calculating the filterability number several parameters are multiplied and divided without giving any special weight to their relative significance, and that there is no characterization of which ones are important and which are not important. Hallen mentioned that Ives had stated that the filterability number is related to the filter material and asked the author to define how it is related to specific parameters, such as the diameter of the media, surface charge, etc. He further asked Ives to elaborate on the response of the filterability number to changes in pretreatment, flow rate and filter media. By way of some example calculations based on data presented by Ives, Hallen demonstrated that for suspensions with similar filterability numbers there may still be significant differences in economic factors of filtration and in parameter significance with respect to filtration optimization. In conclusion, Hallen restated that it could be misleading to lump all parameters in one number which actually has no theoretical significance. He suggested he would prefer the opposite approach of examining each specific parameter to determine how it influences filtration performance.

B.2 Paper No. 13

Molof (USA) commented that the paper by O'Melia and Ali is a significant step in attempting to bridge the gap between the operation of a clean filter and the operation of a filter with depleted capacity, and indicated that the authors' emphasis on the effects of ripening of the filter is welcome. Molof indicated that the authors had stated that, for a given mass, more head loss results with small particles than with large particles, and that the effect of suspended solid size on head loss is dramatic and surprising while small differences result in removal efficiencies. He suggested it would be helpful if the authors could be more quantitative and define what range of particles they describe as small; further, that the effect of small diameter particles on head loss raises some questions concerning removal mechanisms, and asked the authors to comment on several hypotheses he advanced in this regard relating to patterns of attachment and compaction of large and small particles. Molof asked why the authors did not consider particle deposition interactions between collectors or filter grains so that two or more collectors could be treated as a single system, suggesting that this might provide more insight into the question of dendrite growth, bridging, and possibly why small particles cause such high head losses. A final point made by Molof was that a statement by the authors regarding the limitations imposed by very small particles on the effectiveness of multimedia filters was not supported by either their work, or previous observations on filtration of coliform organisms.

B.3 Paper No. 16

Almeida (Brazil) agreed that many of the pollutants of present concern are associated with suspended solids, citing heavy metals as one example, and that effective treatment for removal of the former frequently depended on selection of effective processes for solids separation. He indicated, however, that there are important considerations in process selection beyond those elaborated in the paper; specifically the processing and disposal of the wash water, filter area requirements, economic feasibility, and alternative separation processes such as adsorption on activated carbon. Almeida also asked whether the authors had considered particle destabilization measurements during the experimental work to allow computation of the most effective chemical type and concentration as well as the optimum stabilization level to be achieved.

B.4 Paper No. 19

Picard (France) suggested that additional parameters might be included in the author's model for the precipitation-contact filtration process to facilitate dynamic control; specifically, the time, t_p, to "blocking point," and the time, t_c, to "breaking-through point," as defined by Pelloni in his paper. Picard also asked about the effects of head loss in the different filter layers with respect to determination of the "breaking point" described in the paper.

C. Floor Discussions

C.1 Paper No. 10

Moergli (Switzerland) commented that he had worked for about two years with the Ives' model and found it to be very practical. He indicated that the capacity of the filter medium is very important, and asked whether it is possible to change the filterability number by substituting capacity, Σ, for filtrate quality, C, in the equations.

Boller (Switzerland) had two comments. First, he questioned the significance of the theoretical developments presented in the paper in view of the empirical nature of the filterability number. Second, he agreed that the filterability number may lead to a savings in experimental costs, but expressed doubts if all experimental conditions can be adequately represented in the filterability test. He described some of his own experiments with filtration, and indicated that, depending upon the particular point during the experiments in which it was measured, the filterability number for these experiments would suggest poor filterability for those cases in which he actually achieved the best - from his point of view - filtration results. Boller also asked if surface filtration might produce a good filterability number but perhaps not be a practical alternative.

Kavanaugh (USA) agreed that there is a great need for simplifed methods to evaluate the side variety of chemical conditions that may need to be tested prior to the design of solids-liquids separation processes, but expressed doubt that the system described by Ives is applicable for the particular design of a granular media filter. He asked Ives to comment on the design applicability of measurements made with the filtration instrument. Kavanaugh further asked Ives for his thoughts on the need and/or desirability of extensive flocculation prior to filtration, indicating that this was a question of some debate in the U.S. He, like Boller, also commented on the question of when the filterability number should be measured; that is, whether the filter media should be clean and not used previously, or should a number of runs have been conducted prior to the measurement.

Stone (USA) indicated that there is a standard method commonly used in the United States for measuring filterability - the ASTM procedure. He asked Ives whether he had run tests and compared his results with those of the ASTM standard method, and if so, to comment on the relative advantages and disadvantages of the two techniques.

Author's Reply - Ives commented that Hallen had posed several questions which are important and significant, and repeated that when one is considering optimization and the significance of parameters as they will affect design, it is necessary to carry out a pilot plant experiment with the depth of media that is likely to occur in the practical filter. He indicated that while the test he had described was useful for rapidly studying the effects of certain variables and the sensitivity of the system to changes in these variables, he would never recommend the test for determining the optimum conditions to produce simultaneous head loss limit and filtrate quality limit of a deep bed filter; this, he again emphasized, requires full pilot plant experiments. He commented that he had deliberately made the jump from the K_1 value of theory to his filterability number because concentrations normally in the filtrate are very small and, therefore, the change in filtrate quality $(C_0 - C)$ is a number that doesn't vary very much. A ratio of these two numbers is more likely to be significant and produce a response which is measurable. He noted that he did not defend the filterability number, F, on the grounds of theory. He also noted that on any curve which is not monotonic one can find two points of filterability of the same value. He stated, however, that individual values are not too significant *per se*; rather, that it is the change of values that is important, as well as the minimum region of the filtration. Ives observed that the control of any apparatus is subject to the quality of the operator, but he had proposed a simple filtration apparatus without any type of automatic control or electrical apparatus that would substitute for the operator. Just as a good operator can set up a jar test apparatus and get reliable, consistent results, commented Ives, so a good operator should be able to set up and get reliable, consistent results from his filterability apparatus. He stated that the important parameters are the filtrate concentration and the head loss; these dictate whether a filter is acceptable or not. However, he noted one must not confuse the filtration through a small test filter with the filtration that will occur through 1 m of a practical filter, and that the quality of the filtrate in a small filterability test has no bearing on the concentration that will be achieved in a practical or pilot scale filter.

Ives commented that he did not believe that Σ could be substituted for C in the equations, as Moergli suggested, because there is no theoretical basis, and because Σ requires some calculations which defeat the simplicity of his suggestions, yielding something far more complex which, while having appeal for research workers, would not be suitable for operators.

Ives agreed with Boller that a 10-12 min test does not yield sufficient information for design, and that it is necessary in this regard to use larger scale and longer term pilot plant studies to obtain required design information.

In response to Kavanaugh's comments Ives indicated that the flocculation and mixing required at the scale of his experiments is relatively simple, but that this is quite another question on a larger scale. He stated that clean media should be used for the test because there would be no reference point if one started with a dirty media. He noted that he did not mean acid cleaned, which would yield a different surface chemistry.

Ives indicated that he was not aware of the ASTM test referred to by Stone, but that he would certainly examine it to determine how it compares with the test he has proposed.

C.2 Paper No. 13

Ives (UK) expressed disagreement with O'Melia and Ali on several points of their paper. He first noted doubt that dendrites form in water filtration, indicating that he had never observed dendrite formation in his 20 years of experience with filtration of waters and wastewaters. Ives further commented that the conclusions on p. 173 of the authors' paper concerning influent concentration are misleading. He suggested that the authors' claim that removal efficiency is not independent of influent concentration as filtration proceeds would disagree with the very basis of all modern filter theory developed over the past 25 years. Additionally, he indicated that the authors' conclusion that low concentrations produce low removal efficiencies and therefore filters should be deep for low turbidity water is not valid because the criterion of filter performance is not the removal efficiency as such, but the quality of the filtrate. As a final point, Ives noted that the authors' proposal that shallow filters be used for high concentrations would lead to rapid breakthrough and short filter runs. He suggested that the conclusions advanced in the paper, if taken out of the context of ripening stage effects, would result in poor filter designs.

Pearson (USA) described some of his ongoing work on microparticles and water quality parameters with the Royal Institute of Sweden and the Swedish Water and Wastewater Association. He commented briefly on the findings of this work, indicated that a publication of these findings would soon be available, and that the publication would be sent to those who expressed interest during the meeting.

Author's Reply - With regard to Molof's question about what is small, O'Melia indicated that he considered this to mean 0.5μ in size or smaller. He indicated that he thought that the deposition of small particles is more or less random, and that this is included in an empirical way in the model. He suggested that the interaction between two filter grains is important but beyond anyone's capacity to describe at this time. He noted that the fact that he assumed that the porosity is constant is not especially important, that it could have been included in the model, and probably will be in future calculations.

In response to Ives' comments O'Melia agreed that dendrites have not really been observed in water filtration but that, although this is partial evidence that they don't form, it is not final evidence. He discussed photographs presented by Ives which could be interpreted as indicating that initial deposits of material catalyze further deposits. O'Melia indicated that Ives had made significant comments about the effects of concentration on filtration and had presented a surprising graph showing that efficiency is independent of concentration when he takes into account deposition. He suggested that they may disagree on what efficiency is and, in terms of the efficiency of the filter bed, that he would think that deposition is a function of the concentration of material applied. O'Melia suggested that if one considered filter bed efficiency as a function of depth, without normalizing for deposit, he would expect to find that particle concentration has a significant effect because high concentrations produce large deposits. He agreed with Ives that his statements about the need for deep filters for low concentrations and the possible use of shallow filters for high concentrations should be taken with some care; certainly the actual concentration leaving the filter is what is significant.

With regard to Professor Pearson's data on particle sizes, O'Melia agreed that it is essential to have more data on particle size distributions. He noted that Pearson's data did not show very many particles in the small particle size region, but that this may be attributable to the limit of detection of the counting technique used, which is constrained to particles of about 2.5μ in size or larger. He noted that there is substantial evidence, especially for wastewaters, that there are large concentrations of submicron particles and indeed some evidence that there are submicron particles present in many natural waters; the difficulty is in measurement, even with the coulter counter. He noted that it is possible to extrapolate distributions based on measurements of 1μ or larger down to lower sizes and that it is possible to use light scattering and, possibly, electron microscopy to gain better evidence of such submicron particles. He indicated that such observations will likely confirm that there are substantial contributions made by submicron particles, not only to the number but also to the surface area and volume of material in natural waters and in wastewaters.

C.3 Paper No. 16

Ives (UK) agreed with the authors' doubts concerning collector efficiencies published in the literature of 10^{-4}. He stated, as an example, that in a 1-m deep filter of 1-mm grains, the number of sequential collectors is approximately 10^3. Assuming that the remaining particles in the flow after each collector are uniformly redistributed, the overall efficiency of the filter would be $10^{-4} \times 10^{-3}$, or 10^{-1}; this would suggest that only one in 10 particles is removed by filtration, for an overall removal efficiency of 10 percent. He noted, however, that observed overall removal efficiencies in deep filters are usually 90 percent or better, illustrating that there are yet large discrepancies between observed and predicted single-collector efficiencies. Ives also asked whether there were certain errors in notation with respect to the ordinate in Figure 1 and the top scale in Figure 5 of the paper; specifically, should ΔN_i in Figure 1 be simply N_i, and should the value of 0.1 for l_i on the top scale of Figure 5 in fact be 1.0 instead.

Gujer (Switzerland) expressed doubt that the authors had realistically estimated the degree of association of pollutants with particles which leave the second pretreatment process. He suggested that, due to breakup and reformation of flocs, trace pollutants are likely distributed evenly throughout the flocs and not proportional to surface area. He indicated that if this alternative hypothesis were true, all the conclusions of the paper with regard to secondary effluent would have to be changed.

Author's Reply - In response to Gujer's comments, Kavanaugh noted that the assumption of adsorption of materials onto the surface of particulates is in fact conservative; that is, if the material is incorporated inside the materials a filter would become even more efficient. He suggested, in response to Gujer's comment that perhaps a microstrainer would do the job that a filter would, that his analysis must give way at this point to pilot studies. He noted that observations in the literature indicate approximately 50-60 percent removal of suspended matter by microstrainers, and that, although this might be sufficient, a filter is usually useful for the removal of the smaller particles as well, provided they are destabilized; in particular, a filter has the advantage of being able to remove colloidal phosphorus material. Consequently, Kavanaugh indicated, while the specific conclusions might indicate a microstrainer, a broader analysis of the problem would still satisfactorily identify a filter as a viable alternative. On the larger question of particle distribution and sizes, Kavanaugh indicated that he had observed that size distributions down to about 1μ demonstrate a slope which would suggest that most of the particle volume and surface area is represented by particles in size ranges above 0.5μ. In other words, he noted, the collective parameter of suspended solids is perhaps not such a bad measurement. He commented that in the case of some effluents, however, there has been indication of a large percentage of colloidal materials, which would suggest pretreatment to shift the slope of the size distribution from a high number, say 4, to a small number, say 2, thereby shifting the material into the larger size classes which is what is done in coagulation.

Kavanaugh agreed with Ives regarding his corrections in notation in Figures 1 and 5 of the paper.

Relative to the comments by Almeida, Kavanaugh stated that although he did not measure mobilities for this particular experiment, he had on many previous occasions. Provided the mobility is less than about -1 mobility units, Kavanaugh indicated destabilization and attachment reaches a maximum. With respect to Almeida's question about whether particles in the 0.5-4μ range were still present after coagulation, Kavanaugh noted that the data presented in the paper are for suspensions going directly into the filter and not prior to addition of the coagulant. Nonetheless, he commented changes of particle size distribution just prior to filtration, that is, as the particulates pass down through the water column and approach the filter medium, are significant. He observed that he had one criticism of his analysis from his own perspective; that is, in most systems of flocculated materials particle distributions are not well-defined, and are constantly changing. Nonetheless, Kavanaugh stated size distribution analyses provide additional information for the type of engineering decisions that are of interest in selection of solid-liquid separation processes.

C.4 Paper No. 19

Ives (UK) noted a great similarity between the author's test apparatus and characteristic filtration number, and those presented in his paper earlier that morning. Ives stated that although Pelloni had mentioned in his verbal presentation that these were based on the American methods and on his own, he observed no acknowledgment in the references of the paper to either of these, and stated that he did not remember discussing with Pelloni's company this particular method of filterability. He asked Pelloni how he had derived these relationships, particularly because they are stated in the paper with no explanation. Ives noted that the theoretical model used by the author assumes that the specific surface remains constant during clogging of the filter, and that changes in the porosity are dominant. He stated that this is exactly opposite to the assumption made by O'Melia and Ali in their paper earlier that morning, where they considered the change in the interfacial surface area to be important, while porosity changes were assumed to be negligible. He asked who to believe when such absolutely conflicting assumptions are made. He cited experimental measurements made in Moscow and in London that show that specific surface rises and then falls to a low value, while porosity declines continuously during filter clogging, and commented that these observations support the theoretical models that have been published previously in the scientific literature. Ives noted that the author had, on p. 268, confused Theodore von Karman, the distinguished fluid dynamist, with Dr. P. C. Carmen, who was director until recently of the National Institute for Chemical Engineering Research at Pretoria in South Africa.

Peterson (Sweden) noted that contact filtration has been used in Sweden since 1971, and that today more than 20 contact filter plants are in operation for potable water production and treatment of sewage and industrial wastewater. He suggested that contact filtration is an economic and effective process for phosphorus elimination, but that in a multiple filter plant in practical full-scale operation, his experience would suggest that the backwash program must be guided rather by real filtration time than by pressure drop. He asked Pelloni to comment regarding eventual problems involved in translating his pilot plant tests into full-scale multiple filter operations.

Basalo (France) asked Pelloni to elaborate on his terms "unfiltered" and "filtered" phosphorus. He also asked why the Swiss were of the opinion that the effluent phosphorus levels as low as 0.1 mg/ℓ were really necessary.

Boller (Switzerland) asked for further details on media size, flow rates, and filter capacity of the media. He also noted that Pelloni had not used polyelectrolytes, and asked if he had observed, as had Boller in similar experiments he had done, early breakthrough of the beds, with filter runs of about 10-12 hr being determined by breakthrough and not by head loss considerations. He also suggested that the water Pelloni used for filtration was not very representative of a secondary effluent with respect to suspended solids concentration and that, had a more representative water been used, Pelloni likely would have found it necessary to utilize 40-50 mg/ℓ of iron rather than 5-6 mg/ℓ. Boller indicated that this would likely yield filtration run times which are no longer in the economical range. He expressed doubt, therefore, that Pelloni had really found an improved technology as he had suggested in his paper.

Moergli (Switzerland) noted that Pelloni had used a filter with sand and pumice and that this is more suitable for water filtration than for wastewater treatment. He indicated that the durability loss of pumice is very high (approximately 2 percent) compared to that of sand (less than 0.1 percent), and that pumice is thus not satisfactory for use in a wastewater filtration system. He also noted that there is no intermixing zone between sand and pumice and that an intermixing zone of 10-20 percent is required in such a dual media filter.

Viitasalo (Finland) commented, partly in reply to Basalo's earlier question, that in another session of the Conference a paper was being presented which indicated that phosphorus concentrations of under 0.5 or 0.3 mg/ℓ in effluents was indeed required to prevent eutrophication of receiving waters. He commented that filtration was one of the best methods to meet the effluent requirements. He noted that common practice in Finland is to precipitate phosphorus with ferrosulfate which forms very fine precipitates which tend to escape in the effluents from wastewater treatment plants. He asked Pelloni whether filtration would be an efficient means for retaining these particles without adding additional coagulants or precipitation agents.

Author's Reply - Pelloni indicated that Picard's suggestion to incorporate t_p and t_c as parameters in the model is worth investigating, but that to develop a process which is dynamically controlled, he had selected easily measurable values; t_c and t_p are values which have to be estimated or measured after the filtration run and, therefore, present difficulty for inclusion in a process control model. With respect to the head loss of the two layers and the breaking point of the curve, Pelloni indicated he had not observed this phenomenon, perhaps because the specific head losses for the two media were approximately the same.

Pelloni commented to Ives that the filterability number could be derived by the Buckingham Pi-theory if all important parameters are taken into account. He acknowledged Ives' work on filter theory and the filterability number.

In response to Peterson's comments regarding the principal parameter for backwashing, Pelloni indicated that this depends on the nature of the suspended solids and on the design of the filter, and that it is desirable in any event to "use" the filter as much as possible; that is, to "fill the filter with solids" to the greatest extent possible. With respect to Peterson's question about several filters operated in parallel, Pelloni suggested that a process computer can be employed to control backwash of filters in parallel and for system management to enable use of a minimum storage capacity for backwashing the filters.

Pelloni indicated to Basalo that unfiltered phosphorus is determined on a sample which has not been filtered by a membrane filter prior to analysis, while filtered phosphorus is that which passes a membrane filter. He noted that the phosphorus limit has been established by the Federal Institute of Water Pollution Control and other agencies in Switzerland, and that he has been concerned only with whether it's possible to reach the limit.

Pelloni indicated to Boller that the mean grain size of the sand was 0.75 to 1 mm and the pumice stone was 1 to 2 mm in diameter. The filtration rate, he noted, ranged between 8 and 10 m/hr. Relative to the capacity of the filter, particularly filter run time, he noted that it is a question of how one performs the crystallization process to obtain a certain particle size distribution.

Pelloni suggested that Moergli was referring to a bed which is not really separated. He indicated that Moergli's comments were of interest, and that he would like to pursue them with him in more detail since the time remaining in the session was insufficient.

To Viitasalo's comment, Pelloni replied he could not give an answer because only 10 percent of the influent phosphorus was particulate in the water with which he worked; the bulk (≈ 90 percent) was soluble phosphorus.

IV. CRITIQUE OF SESSION

Each of the papers in this session, but particularly those of Ives and O'Melia, generated substantial interest and discussion. Considerable controversy over the respective treatments and interpretations of theory, observation, and practice advanced by the several authors developed in the course of the discussions. The papers were clearly of interest to the audience and, at least in this regard, were well chosen. They clearly dealt with a subject of increased concern and re-intensified interest in water pollution research and practice.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Deep bed filtration is emerging as an important unit operation in wastewater treatment. This is attributable in part to increasingly stringent discharge requirements and in part to the increasing awareness of the role of suspended solids as "carriers" of pollutants of concern. One factor that surfaced clearly during the course of this session is that, despite extensive experience with deep bed filtration in water treatment, there is yet much to be learned regarding filtration theory and optimum application. The process is much more complex than simply one of "straining" suspended particles. The solution chemistry and physicochemistry associated with particulate removal in deep-bed filter systems is complex, particularly with respect to waste treatment applications. In view of the increasing import of the process for wastewater treatment, and in view of the lack of refinement of associated process dynamics, deep-bed filtration would seem an important area upon which to focus further research efforts in the U.S.

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: B
Time: 9:00 am to 12:30 pm

B. Theme of Session: Measuring and Modeling the Influence of Wastewater on Coastal Areas

II. REVIEWER

A. Name: N. Bruce Hanes

B. Position and Affiliation: Professor and Chairman
Department of Civil Engineering
Tufts University
Medford, MA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 11: "Predictions of Bacterial Pollution in Sea Water," by T. Omura, J. Matsumoto (Japan)

The paper was concerned with the survival of indicator bacteria in Onagawa Bay which is located in northern Japan. A knowledge of the behavior of microorganisms and the ability to predict bacterial levels in the sea water would be useful in managing the shellfish and kelp harvesting for human consumption. The authors investigated the coliform group and enterococcus density as well as temperature, transparency, pH, Cl, BOD, COD and DO during 1974. The statistical character of the coliform group density and the enterococcus density are examined and the principal component analysis technique was applied to evaluate the degree of water pollution. In addition the distribution of bacterial density was predicted by numerical analysis using the mass balance equation and employing the finite difference method. The results of the study may be summarized as follows:

1) While both the coliform group and the enterococcus density are greatly reduced the reduction is greater in the coliform group;

2) The probability distribution of the coliform group density, the enterococcus density, transparency, BOD and COD are logarithmically normal;

3) Bacterial densities are positively correlated with temperature, BOD, COD and are negatively correlated with transparency, pH, Cl and DO;

4) The coliform group density enterococcus density, pH, BOD and COD are correlated with principal component 1;

5) Good predicted bacterial densities were obtained using Kc = 5.0 and Ke = 4.0.

A.2 Paper No. 14: "The Use of Indium 113 for the Measurement of Coefficients of Dispersion in the Sea," by J. Godin, P. Marchandise, P.J. Rousselin (France)

The authors reported the development of a relatively simple method for measuring the coefficients of dispersion of a wastewater discharged into the sea. The approach was to use a short-cycle radioactive tracer (indium 113^m) to determine the principal dispersive properties of the receiving medium. The dispersion model employed was derived from Fick's law. Concentration measurements were made at depths of 40-50 cm, 1 m, and 2-3 m to eliminate the effect of the wind. The model was used to predict the pollution pattern of future wastes by applying the coefficients of dispersion determined experimentally.

A.3 Paper No. 17: "Mathematical Modelling of Eutrophied Coastal Areas," by K. I. Dahl-Madsen (Denmark)

Combined hydrodynamic, transport-dispersion and eutrophication models were developed and utilized in the Danish wastewater planning process during the period of 1970 to 1977. The water quality of 15 marine coastal water systems was described by means of 5 to 14 state-variables in 10 to 100 points of space. The major objective of this effort has been the development of sophisticated models for phytoplankton growth including intracellular nutrients while maintaining a firm hydraulic basis. A comprehensive evaluation of field and model data indicates that the agreement between observed and simulated values of state-variables must be improved by further model development.

A.4 Paper No. 20: "Water Conditions in the Stockholm Archipelago after the Introduction of Biological and Chemical Purification of Wastewater," by M. Cronholm, K. Bennerstedt (Sweden)

The inner part of the Stockholm Archipelago receives wastewater from a population of 860,000. Biological and chemical purification of all wastewater discharged to the inner archipelago was initiated during the period of 1970-1973. As a result of this effort, hydrogen sulfide has only been recorded in the bottom water while the phosphorus content of the surface water has decreased. This improvement has also been reflected by a decrease in the chlorophyll content and an increase in transparency (0.5 to 1 m) in the outer archipelago. Budget estimates indicate that phosphorus sedimentation has decreased, phosphorus release from the bottom was large in 1974 through 1976, and a considerable loss of nitrogen occurred as a result of denitrification.

It is suggested that an effective decrease in oxygen consumption of the wastewater could be achieved by the oxidation of the ammonium in the wastewater to nitrate at the purification plants. It was further suggested that nitrification could be limited to the months of July through October which is the critical period. It was also suggested that a decrease in the discharge of oxygen-consuming substances should improve phosphorus in the sediment.

B. Prepared Discussion

B.1 Paper No. 11

Ludwig (Brazil) suggested that water temperatures may be the most important factor affecting bacterial survival and that while it was not discussed, the data suggested survival times in cold water rather than tropical waters. He also requested that the results be recorded in terms of T_{90} as well as K rates. Ludwig also noted that while laboratory studies are important and have a place, he felt that it was futile for the authors to compare the results from their field studies with laboratory work because of the complexity of the natural system. He suggested that the BOD values of the sea water in this study should be presented because it was his impression that they were high. Finally, he requested that the authors describe their laboratory techniques.

B.2 Paper No. 14

Porte (France) expressed a strong interest in this paper because of the development of dispersion models in the sea by his group. He noted that theory alone could not describe the phenomenon, thus the need for reliance on models developed from field experience. He presented two dispersion models, one for the case of an instantaneous pollution source and the other for a continuous source. He closed his discussion expressing a concern with the safety aspects of using a radioactive tracer when not necessary as well as the additional cost.

B.3 Paper No. 17

Barrett (UK) noted that the paper dealt with the difficult area of environmental modelling and that while the author concluded that he felt his model needed more work, the comparisons between calculated and observed values for inorganic phosphorus, primary production, phytoplankton carbon, and inorganic nitrogen represented good agreement. Barret emphasized the complexities of describing both the biological and chemical phenomena and noted that the author had used a single species model. Nevertheless the model presented is detailed involving five dependent systems including the influence produced by three external parameters; thus, it is necessary to use 11 equations with 35 parameters to describe the ecological systems. Barrett requested the sources of the values given for the parameters and noted that the accuracy of the model depends heavily on these values. He went on to discuss the common problem of accumulating sufficient data to determine if a model is actually typical for a range of values. He closed the discussion by emphasizing that the model was adapted to oligotrophic waters with small amounts of nitrogen. Barrett expressed his doubts that the single species model would be useful in eutrophic water with ammonia contents of 5 to 10 mg/ℓ.

B.4 Paper No. 20

Pearson (USA) commented that he was pleased to see both an engineer and biologist, an ideal combination, as authors of the paper. He posed seven questions, several addressing the differences between customs and terminology in Sweden and the United States. The questions were:

1. Frequently BOD_7 is used in Sweden because of work schedules; BOD_5 was reported in the paper. Were the values for BOD_5 actually measured or calculated from BOD_7 data?

2. When the term ammonium is used in the paper is it actually total nitrogen?

3. What is the state of nitrogen with respect to oxidation as it is discharged from the treatment plants?

4. The form of nutrients, particulate versus soluble, may influence the availability of nutrients. In this study what was the form of nitrogen and phosphorus?

5. How sure are the authors that phosphorus is the limiting factor? Could it be nitrogen or some other factor?

6. How good is the parameter mg or g/m^2? Pearson expressed serious doubts that the parameter is related to the biological processes.

7. Have you looked seriously at quantitative description of planktonic or benthic organisms?

C. Floor Discussions

C.1 Paper No. 11

Grabow (South Africa) raised two questions. First he requested that the authors detail the bacteriological methods used in the study. Second he asked if they had either experimental data or knowledge of other studies that provided information on the survival of enteric virus or bacteriophages in sea water.

Shuval (Israel) noted that earlier work of Gameson (England) which indicated the inactivation of coliform in sea water by light, and suggested that the negative correlation between transparency and other coliform counts in this study reflected this relationship. He also reported unpublished data collected during the past 15 years on beaches located in Israel which indicate that temperature and light are the strongest predictors of coliform density in sea water. He then referred to an Australian paper which demonstrated that when temperature was held constant, light demonstrated the greatest influence on T_{90}. As a result of these studies and experiences, Shuval hypothesized that when a sewage plume is trapped beneath the water surface an increased health danger may be present because of the prolonged survival of microorganisms that are not exposed to light. Shuval closed with a reiteration of his concern about the presence of viruses in sea water. He noted that their group could now detect the presence of polio, coxsackie and echo viruses in 100 to 1000 ℓ of sea water with coliform counts of 50 to 150 per 100 mℓ. He suggested that as a result of this fact the coliform organism may not be the long term predictor of public health risk.

Ramadan (Egypt) expressed his conviction that the enterococcus group was the best indicator of fecal pollution in sea water. He cited the short survival time of the fecal coliform group in sea water as his major objection to their use as an indicator organism. He also noted if coliform organisms were to be used, he felt that the total coliform group would serve better as an indicator in sea water because of their diversity. Finally, he expressed his personal belief that he did not believe in statistical analysis of bacterial data because of the great variability in bacterial response to different factors.

Crouzet (France) requested more precise information on the variation of the data. He was also interested in the sensitivity of the model to the different parameters that were measured. Finally he also noted that light was important and that it was related to the transparency factor measured by the authors.

Somlyody (Hungary) presented four questions:

1. Were the advective terms in the solution of the Navier-Stokes equation neglected?
2. When solving the transport equation some numerical diffusion and dispersion will occur and therefore it is necessary to test whether the wave is distorted. Was such a test made?
3. How did you estimate the diffusion coefficients?
4. What is the execution time of the computation?

Author's Reply - Omura indicated a temperature variation in the bay of between 10 to 25°C. He also indicated that the seasonal variation of bacteria, BOD, COD were comparatively small (Table 3). He stated that standard methods had been used, membrane filter in the case of coliform and MPN in the case of the enterococcus group. Finally, he responded that the equivalent T_{90} for the laboratory work of Hanes was 24 hr for the coliform bacteria and 49 hr for the enterococcus group. This compares to 11 hr and 14 hr, respectively, in this study.

C.2 Paper No. 14

Pomeroy (USA) stated that his comment was concerned with terminology. He noted that it was stated in the paper that the dispersion model was derived from Frick's Law. He also noted that the apparent Frick's coefficient changed with the scale of the phenomenon, thus changing with time. As a result, the process is not actually described by Frick's Law and it would be better to use some other terminology.

Author's Reply - Godin indicated that if Frick's Law describes molecular diffusion, it does have a constant diffusion coefficient. In this case he would prefer the term dispersion coefficient because in addition to molecular diffusion the coefficient also depends on the tide (height, etc.). He also responded that it was more convenient to use the radio-active tracer because of his experience in laboratory work and the availability of instrumentation. Thus, its use was not more expensive than dye. Finally, he reported that indium 113^m belongs to Group 3 of radio-active materials and is not very toxic as well as being gone in 24 to 48 hr. He reported that proper precautions were taken in its handling and application.

C.3 Paper No. 17

Hahn (Germany) raised six short questions. They were:

1. In minimizing the state-variables, where do you cut off the food chain in sea water, especially when predator-prey relationship may be more important than in fresh water?

2. Did you consider autolysis with the release of phosphorus?

3. Where did you obtain your rate constants?

4. How did you validate your model and how different were the values for calibrating the model?

5. What boundary values did you use (average, least favorable, etc.)?

6. Why construct treatment facilities in the case of Storstrommen (Figure 15)?

Montgomery (UK) was interested in obtaining more information concerning the difficulties the author had experienced with the cycling of nutrients between the sediments and macrophytes. He related difficulties he had encountered with the same problem and had found it to be influenced by nitrogen, phosphorus and an unidentified agent.

Somlyody (Hungary) suggested that a sensitivity analysis be performed to reduce the number of parameters.

Author's Reply - The sources of the values for the parameters are the literature, laboratory experiments, and the calibration of the model. A brief sensitivity analysis was made and the five parameters that are varied in this study were found to be the most sensitive. The model has not been verified from the point of view of looking at one system before and after the addition of treatment. It has been verified, however, by its application to several different systems. The measurements used for the calibration of the model were from general water quality surveys. This model, as suggested by Dr. Barrett, could not be used in cases of high ammonia concentrations. If it were to be used for such a case, at least one more state-variable would be required. To Mr. Hahn the problem of the food chain is difficult. The problems of the higher food chain levels would make the model much more complex and it is felt that actually not enough is known to describe the phenomenon. In the case of boundary values, we use the measurements established in the measuring period calibration situation. When the influence of a given wastewater scheme is evaluated, there is no policy in Denmark at this time (average vs. extreme values). As a result, both may be used depending on the circumstances. In response to the comment concerning the need for treatment in our example of Storstrommen, this case illustrates the usefulness of the model in the management decision that treatment is not needed. Finally, we have made a few computations on the macrophytes production and find it to be a most complex and difficult problem. We have given the problem a high priority in the future, however, because of the importance to be able to describe plant secession in an area as the sewage discharge changes.

C.4 Paper No. 20

Grabow (South Africa) inquired if the authors had any data on the fecal organisms associated with pollution in the Archipelago which are important from a health point of view. He noted the earlier paper of Omura (Japan) in this session which suggested that high loads of organic materials prolonged the survival of fecal microorganisms.

Taylor (New Zealand), a chemist, agreed with Pearson (USA) in calling for more specificity when describing chemical parameters. He also noted that blue green algal growth is frequently related to high pH and temperature and requested the range of pH and temperature during the study period. Finally, Taylor was interested if any consideration had been given to the cost of direct oxygenation of the bottom waters compared to the removal of nitrogen from the wastewater treatment plant effluents.

Author's Reply - In Sweden an inhibitor is used in the seven day BOD test to produce values comparable to BOD_5. This is done simply because of work schedules. The term ammonium in the paper means ammonium, not total nitrogen. Further, nearly all the inorganic nitrogen discharged from the wastewater treatment plants is ammonium. In the case of phosphorus, only about 30 percent is believed to be soluble while the balance is particulate. The question with respect to phosphorus actually being the limiting factor is important and has been discussed extensively. Actually, the limiting factor changes. For example, at one time it was nitrogen and now the best information available suggests that phosphorus is now limiting; however, it is acknowledged that it is difficult to be certain.

Also in response to Pearson, biological studies have been made but are not included in this paper. Finally with respect to health aspects, it is known that *Salmonella* and poliovirus can be isolated from the wastewater; however, there are no data that relate their presence to fecal indicator organisms. The other author (Bennerstedt) indicated that the blue green algae disappeared below temperatures of 10-13°C. He also noted that pH values were not recorded in this study. Finally he reported that because of the large volume of the bottom waters, direct oxygenation would not be practical when compared with converting the ammonium in the wastewater to nitrates.

D. Other Observations and Comments

The feeling expressed by several participants is that modeling of environmental systems is most complex and difficult although there appears to be agreement that progress is being made. Goettle (Federal Republic of Germany) expressed the opinion that a model should be as simple as possible to be cost effective in its application. He suggests that 20 parameters may be an upper limit. Somlyody (Hungary) noted that about one-half of the models are simple in nature and have been applied to actual projects although they have an important parameter omitted. He went on and suggested that the other half of the models available are complex but have not been verified under actual field conditions. He stressed his opinion that sensitivity analyses should be used to narrow down the number of variables in the more complex models so that they can be applied to real problems. It is apparent that models for all environmental studies are not available on the shelf; however, this reviewer was impressed with the progress that has been made to date.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The information presented in this section is difficult to evaluate from everyone's viewpoint. I will suggest, however, possible applications from a single point of view (mine) for each paper. Paper No. 11 dealt with bacterial pollution of sea water and developed a model that predicted bacterial survival in an ocean environment. This paper may find application to some of the recent health problems experienced with shellfish in Louisiana in our country. Paper No. 14 described a method for determining dispersion coefficients in sea water. This approach may be useful in studies that are currently being conducted involving the dispersion of wastewater in the ocean from some of our coastal cities. The mathematical model developed in Paper No. 17 is the most sophisticated this reviewer has examined. While it was recognized that deficiencies existed, it clearly will be of interest to individuals making a similar effort in the USA. Finally, the review of water conditions in the Stockholm Archipelago, after the initiation of biological and chemical purification of wastewater, will be of interest to decision makers facing similar problems in the USA. For example, Paper No. 17 (and 20) may be particularly helpful with respect to determining the degree of treatment wastewater should receive in Hawaii.

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: C
Time: 9:00 am to 12:30 pm

B. Theme of Session: Removal of Nitrates in Wastewaters using Biochemical Denitrification

II. REVIEWER

A. Name: Davis L. Ford

B. Position and Affiliation: Senior Vice President
Engineering-Science, Inc., and
Adjunct Professor
The University of Texas at Austin
Austin, TX

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 12: "Multicomponent Diffusion and Denitrifying Biofilms," by M. Riemer, D. Harremöes (Denmark)

The major objective of this paper was to evaluate diffusion rates of substrates from the bulk liquid into a fixed film as well as to study out-diffusion of biochemical oxidation products in order to develop diffusion models for denitrifying biofilms. The authors used a pilot plant reactor and a methanol-nitrate substrate to develop the basis for these diffusion models. The basic concept considers in-diffusion of the electron donor (NO_3-N), the electron acceptor (methanol) and nutrients from the bulk of solution to the biofilm and the out-diffusion of the products which include nitrogen gas, bicarbonate and carbonate. The authors have proposed that 1/2-order kinetics are a good approximation when substrate concentrations exceed the Monod constant, K_s, by a factor of four to five. It was stated in the verbal presentation that a fixed film reactor for denitrification is nitrate-limited in theory, whereas in practice, the filter was actually methanol-limited.

Particular attention was given to the respective diffusivity rates of nitrate and methanol. The rate of removal of nitrate and methanol from the liquid phase was used as a basis of predicting diffusivity of the respective substrates. As the nitrate-ion was diffused into the biofilm more than expected, it was hypothesized that electrical forces act on the nitrate-ion but not on the neutral methanol molecule. Therefore, the authors state that electrical forces are expected to influence transport of ions into the biofilm. An explanation of the postulated influence of these electrical forces on the diffusion was presented in the paper.

The authors concluded that 1/2-order kinetics can be used to approximate substrate diffusion rates for two component and three component systems as well as possibly predicting out-diffusion of the denitrification products. They also noted the out-diffusion dependence on pH of the fixed film and suggested that the precipitation of calcium phosphate inside the biofilm might possibly be attributable to the luxury uptake of phosphorus. It was the intent of this work to give a better insight into the transport of the substrate into the film and the products out of the film into the liquid phase. Moreover, the theory of diffusion limitations described by the authors serve as their basis for explaining that the rate of denitrification is unaffected in biofilms even when dissolved oxygen is present in the bulk liquid.

B.1 Prepared Discussion

Martin (France) in his formal discussion first pointed out that the assumption that diffusivity rates in biofilms are similar to those in water is possibly not valid. He stated that you cannot calculate diffusion rates of nitrate and methanol in pure water, then extrapolate to substrate-biofilm interfaces. He further stated that the diffusion coefficient varies with the nitrogen and oxygen concentration as well as the level of other products, and indicated that the authors should have included this fact in their discussion. He also noted that denitrification in the presence of oxygen can best be explained by the low diffusion coefficient of oxygen into the film and that the authors should have further developed this concept. In elaboration of the role of oxygen on denitrification, he questioned the authors on data relative to the thickness of the film, the degree of agitation, and the role of turbulence in the submerged filter. He stated that the diffusion of methanol is quite good because of its small molecular size and questioned the authors if the model can be generalized for carbon sources of larger molecules.

C.1 Floor Discussions

Ramadori (Italy) simply made the statement that the diffusion rate of the substrate is the limiting reaction in the filter.

Gujer (Switzerland) questioned if the ammonia-oxygen ratio had any effect on the diffusion rate and questioned the authors as to the depth of substrate penetration into the fixed film.

White (UK) indicated that methanol is quite costly and questioned the authors about the residual methanol in the liquid phase as shown by the data and the efficacy of this practice based on economics.

Author's Reply - Harremöes first stated that diffusion in clear water and biofilms can be related. He also elaborated that the out-diffusion of molecular nitrogen forms bubbles and is possibly responsible for breaking off the film, changing the surface area charge, and thereby affecting the kinetics. He stated that the thickness of the film was important and that the thicker the film, the greater the effective depth, and consequently the more efficient the system.

A.2 Paper No. 15: "Denitrification Kinetics in a Submerged Rotating Biological Disc Unit," by Y. Watanabe, M. Ishiguro (Japan)

The authors in this paper presented a simplified model describing the removal of nitrate in a submerged biological disc unit. The justification of this paper was based on the fact that steady-state kinetic models have never been fully developed for the reduction of nitrate in anaerobic RBD applications as they have in aerobic ones. The authors described the nitrate removal basically as a phenomenon which includes the diffusion of the substrate from the bulk liquid to the surface of the biological film, the diffusion of the substrate within the film, and the biochemical reaction within the biological film whereby nitrate is removed biochemically via denitrification.

The authors used a pilot-scale reactor, feeding a nitrified sewage whose nitrate concentration was controlled by the addition of potassium nitrate. Methanol was used as the hydrogen donor at a methanol to nitrate ratio in the feed of three to one. The authors presented data indicating the relationship:

$$C_o/C_e = 1 + K^* (A/Q)$$

where

$$K^* = (1/K + 1/K_s) - 1$$

The authors showed the overall rate constant decreased with the increase of effluent nitrate concentration. They also indicated that the diffusion term and reaction term became approximately equal when the effluent nitrate concentration was 4 mg/ℓ with a stagnant liquid film thickness of 60 μm. They stated that once the effluent nitrate concentration exceeded this amount, the denitrification process became a reaction-controlled one.

B.2 Prepared Discussion

Hultman (Sweden) first questioned the straight-line plot shown in the paper, Figure 7, when the flow rate variation was so small. He questioned the feasibility of formulating this kind of relationship with only a slight variation in hydraulic flow rate, Q. He also questioned the authors on the accuracy of determination of the thickness of the biofilm layer and stated that there were many vagaries in such a determination. He also questioned the authors as to what impact the change in disc velocity had on the results. He suggested that the authors fully elaborate on the development of these kinetics with respect to the variables to disc speed, the type of energy source, the type of electron acceptor ($SO_4^=$, CO_2, H_2O_2, NO_3^-, etc.) hydraulic loading, and peripheral disc velocity.

C.2 Floor Discussions

Harremöes (Denmark) indicated that the authors' equation 11 was shown as first order and should in fact be 1/2-order.

Gujer (Switzerland) also questioned the authors as to the scale-up problems of the process and verification of the model under full-scale conditions, as well as inquiring about the impact of rotational speed.

Author's Reply - The author did not fully respond to the questions, but simply indicated that the disc diameter and rotating speed will affect the kinetics of the process.

A.3 Paper No. 18: "Treatment of Nigh Nitrate Wastewaters by Plastic Media Anaerobic Filters with Particular Reference to Latex Processing," by G. K. Anderson (UK)

The author of this paper presented pilot plant results of an anaerobic filter using plastic media treating an industrial waste with high nitrate concentrations. The justification of the nitrate removal concept was based on the eutrophying potential of a high nitrate effluent, possible infantile cyanosis, and to the fact that stomach cancer has been tentatively related to ingestion of high nitrate liquids. This latex processing wastewater had a concentration of nitrate in the range of 1000 mg/ℓ as compared to domestic wastewater concentrations of 20 to 40 mg/ℓ (as N). It was stated at the outset that methanol could not be used as a carbon source as it is quite expensive in the plant location in Malaysia. Consequently, brewery wastewaters were used as the carbon source in the pilot plant evaluation. Particular emphasis was placed on determining the optimum COD to NO_3-N ratio. A wide range of COD to NO_3-N ratios were investigated, insuring that the quasi-steady state conditions were achieved when the COD and nitrate removal, gas production rate, and gas composition became constant. Several variables were analyzed by developing plots in the paper, but no general model was proposed. The author simply indicated the efficacy of removing nitrate using anaerobic filters, and underscored the fact that an optimum COD to nitrate ratio does exist. He stated, however, that this optimum ratio, the influence of hydraulic and nitrate nitrogen loading rates, and other variables will depend on the nature of the carbon source, thereby proposing that these parameters should be investigated on a case-by-case basis as different carbon source substrates are used.

B.3 Prepared Discussion

Pohland (USA) gave a rather extensive discussion of this paper. The specific question asked were:

1. How can data be used for full-scale design?
2. It would have been desirable to cite the wastewater characteristics of the latex waste as compared to the synthesized wastewaters used in portions of this experiment.

3. Was nitrate or carbon the limiting substrate?

4. How were the anaerobic columns actually operated?

5. Were parameters other than COD and nitrate monitored?

6. What was the actual fate of nitrogen in the system and was there any attempt to make a nitrogen or carbon mass balance?

7. How can data from different packing be normalized and how significantly are these results influenced by intersticial velocity?

Pohland was quite critical of quantification of the nitrate loading effect as a function of dilution rate and indicated that steady-state conditions possibly were not attained. He cited that co-variations could be attributable to some of the results presented by the author.

C.3 Floor Discussions

Sutton (USA) noted that sludge age values of 86 to 200 days were presented in the authors' Table 4 and questioned the method of calculating these values. He also questioned the possibility of short-circuiting and plugging in the upflow columns, asking if a true fluidized bed reactor was possible.

Waldmeyer (UK) questioned the economics of the process as well as the pretreatment steps that might be required.

Van der Meer (The Netherlands) asked about the extrapolation of kinetics from batch or semicontinuous reactors.

Harremöes (Denmark) calculated K_s values from Table 3 of 1300, indicating there certainly was some mistake.

Author's Reply - Anderson answered only a portion of the questions indicating that solely nitrogen and CO_2 were measured in the gas analysis. He stated that the sludge age values were simply calculated and he did not elaborate on this further as well as the other questions posed to him.

A.4 Paper No. 21: "Denitrification of a Concentrated Nitrogenous Industrial Effluent using Packed Column and Fluidized Bed Reactors," by J. Bosman, A. Eberhard, C. Baskir (South Africa)

The authors presented a very informative paper citing the results from pilot plant studies treating wastewaters from a fertilizer and explosives plant in South Africa. The high nitrate load to the receiving environment had to be reduced prior to land-spraying on pastureland used for cattle grazing. The nitrate-nitrogen concentration was approximately 1400 mg/ℓ. The pilot studies involved both a packed column reactor and a fluidized bed reactor, using molasses as a carbon source. The use of molasses was based partly on economics as it reportedly can be obtained in South Africa at only a portion of the cost of methanol. Moreover, the reaction rate for denitrification using molasses was better than methanol.

The overall removal efficiency of nitrate-nitrogen in both reactors was dependent on temperature, pH, COD, and hydraulic conditions in the reactor. Each of these parameters were optimized in the pilot plant studies. Particular attention was given to the linear flow velocity and temperature as these two parameters were considered to be vital in the overall process performance. As denitrification promotes a rise in pH by virtue of hydroxide production, pH control was imposed with the optimum pH limits being in the range of 7.0 to 7.8. The nitrate removal rate per unit of reactor volume was the primary efficiency parameter used in these studies. The recycle rate to the reactor was used to vary the linear flow velocity and the optimum denitrification was found to occur within the defined range of this velocity. The lower range was determined by the absence of acid formers, whereas the upper limit of linear velocity was determined by the rate of biomass washoff and a corresponding deterioration in plant performance.

The authors concluded that over 90 percent of the nitrate-nitrogen could be removed through denitrification using both the packed column and fluidized bed reactor technology with molasses as a carbon energy source. They found that the fluidized bed reactor was more efficient than the packed bed column reactor in terms of nitrate removed per unit of reactor volume. They noted a particular drop off of process efficiency at lower temperatures and suggested that external heating might be required to maintain process performance during the winter months.

B.4 Prepared Discussion

Moreaud (France) questioned the necessity of having the high recycle rate in the fluidized bed reactor and asked the authors about the efficacy of applying the effluent from these reactors for land application.

C.4 Floor Discussions

Sutton (USA) asked if foaming appeared in the fluidized bed and, if so, to what was this attributed. Sutton also questioned whether the biomass stripping was attributable to turbulence or nitrogen gas production and inquired as to the biomass concentration measured in the bed.

Bernard (France) questioned the settleability characteristics of the biomass out of the reactor, asked the author as to the duration of the test, and asked about NO_2 formation.

Molof (USA) questioned the authors about the energy requirements for the process, inquiring if the authors had made a power comparison between the packed bed and the fluidized bed studies.

Pretorius (South Africa) asked if the end-product was nitrogen gas or N_2O. He also inquired as to what time was necessary to attain a steady-state at the various temperatures.

Author's Reply - The author indicated that a high recycle was energy-consumptive and uneconomical, but necessary to maintain process and performance because of the high nitrate concentration in the wastewater. The author indicated that the recycle ratio was adjusted as the influent nitrate concentration changed. In response to the floor discussion, Bosman stated that the sludge separation from the reactor was quite effective. She attributed the foaming in the process possibly to the molasses, as no foaming was observed when the methanol was added in the comparative studies. She stated that a bed expansion-linear flow velocity curve was developed for these studies. In response to further questions, she indicated that effluent COD was in the range of 2000 to 3000 mg/ℓ, primarily a residual from the molasses addition. She stated that NO_2 formation was never detected, that the power consumption was very high, but they knew of no other alternative, and that the time required to reach steady-state was approximately three to four weeks.

IV. CRITIQUE OF SESSION

There was a significant amount of interest in the session as nitrate removal is becoming more in vogue, not only in the United States but also in many of the more developed countries. This interest was apparent based on the amount of floor discussion as recorded in Section III of this report.

The quality of three of the papers, namely Paper No. 12 (Riemer *et al.*), Paper No. 15 (Watanabe *et al.*), and Paper No. 18 (Anderson *et al.*), was considered both by the discussors and by the author of this report to be of rather low quality. It is important to note, however, that all four of the papers either underscored previously known factors which influence denitrification, or presented concepts not yet fully developed or understood. These two factors represent the most positive aspects of the session in terms of catalyzing thought and future research while the most disappointing feature was that judgmentally, only Paper No. 21 had any real practical value. Another positive feature was the excellent quality of discussion, both prepared and from the floor. These discussions adroitly pointed out weaknesses in the papers, enhancing the overall technical "usability" of the session.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

One must assume that the most significant incentive for removing nitrates from municipal and industrial wastewaters is the potentially adverse effect of its presence in drinking water. This is reflected in the primary nitrate standard of 10 mg/ℓ (as N) as authorized by the Safe Drinking Water Act (PL 93-523). To a lesser extent, the eutrophying potential of effluent nitrate is an environmental concern. Given these incentives, the need for research in the area of nitrate removal is obvious. In this context, there should be added emphasis on the biological removal of nitrate as this is the most cost-effective, albeit potentially unreliable, of the candidate nitrate removal processes. The real need in the United States, therefore, is a combination of case history documentation and practical research in the area of biological denitrification.

A review of case histories should include documentation of European experience, as biological denitrification has been practiced there for many years, particularly where effluents are discharged into water bodies used for drinking water. The variables mentioned in the papers of this session should be quantified as much as possible, both in case history review and in research projects.

I. SESSSION

A. Day: Tuesday, June 13, 1978
Hall: A
Time: 2:00 to 2:45 pm

B. Theme of Session: Land Application of Sludge

II. REVIEWER

A. Name: B. P. Sajik

B. Position and Affiliation: Dean, College of Sciences and Mathematics
The University of Texas at San Antonio
San Antonio, TX

III. REVIEW OF SESSION

A. Formal Paper

A.1 Paper No. 22: "Heavy Metals in Soil and Cereals Fertilized with Sewage Sludge," by I. Viitasalo (Finland)

Viitasalo categorized metals as biogenic (effectively metabolized) or non-biogenic (accumulated, not readily metabolized) as follows:

Biogenic Metals	Non-biogenic Metals
Iron	Mercury
Zinc	Cadmium
Copper	Lead

He then characterized the use of sludge produced in the Helsinki municipal region (two-thirds to fertilizer or compost).

This paper attempted to answer the following questions via a field study carried out from 1970 to 1975:

1) Where do metals accumulate and move in soil?

2) Do heavy metals accumulte in cereals?

3) Can we differentiate accumulation from travel of metals?

4) What are the residual effects of heavy metals in soil?

The experimental design used was to dose agricultural plots with a) 8 tons total solids/yr, or b) 18 tons solids/yr, or c) 30 tons solids/yr. The cadmium levels in the sludge ranged from 10-22 ppm. Viitasalo assumed the medium dosage plot received a medium cadmium level, i.e., 0.3 kg/ha/yr, and then calculated the level in seed crops as 0.00038 kg/ha/yr in the seeds! The data for "release from topsoil" and for "uptake by seeds" were calculated rather than experimental data. From the data, it is clear that 1) the level of cadmium in the soil may, if high enough, influence the cadmium content in grains cropped on such land, and 2) the data as presented are not sufficient to justify continued use of the vague phrase "released from the topsoil" to account for differences between that level measured in the soil plots and that amount added in sludge to those same plots.

The municipality used a sludge spreader application (but no mention is made of percent solids). Helsinki is not an industrialized city but cadmium and other heavy metals do occur in sludge. Viitasalo argued for the cost benefits utilized for agricultural purposes. He felt, however, that heavy metal inputs must be source controlled stating that all other solutions to the problem are inadequate.

B. Prepared Discussion

Kinmont (Switzerland) noted that in Switzerland, 20 percent of the sludge produced by municipal wastewater treatment is now used for agricultural purposes. He favored increasing this use and felt there is no harm in the cadmium levels reported in grain crops. He asked for the promulgation of standards, i.e., zinc equivalents, an allowable increase of 250 ppm in 30 yr as used in Britain, or that doubling be allowed in 50 yr as done in Holland. In the U.S., it is proposed cadmium be limited to 1 percent of Zn applied. Kinmont was concerned with soil pH (especially in terms of metal movement).

C. Floor Discussions

Jenkins (UK) noted that tne data are imprecise as to metal content of soil/sludge. The author needs a better methodology for sampling. Jenkins gave his own work on that problem, saying that in 16 cycles he could extract only 1/60 of Zn, no iron, 1/7 of Ni, 1/350 Cu. He studied mixtures of sludge and sand and found differences in the amounts of extractable metals. These data suggest one cannot draw any conclusions vis-à-vis pollution of groundwater. Then he spoke about reclamation of a power station fly ash deposition with sludges. In his experience, 12 in. of industrial sludge (with heavy metal) gave initially poor yields of grass and then, in the fifth year after application, the grass stands improved.

Author's Reply - Norms are needed, but not yet standardized as to level and time. All norms used are statistical norms not based on plant crop grown or plant physiology. The best norms were felt to be those of WHO.

Jenkins is right about the difficulty of analysis. He felt his high loads were accurate and statistically correct but his low loads were in error.

The author stated further (citing the literature) that as a function of time, cadmium in the soil becomes less available to plants. His own data are consistent with this conclusion. The important data one would wish to see were not presented in the paper. These are:

- soil pH of test plots
- total precipitation during this study (and its frequency, intensity)
- metal monitoring of groundwater via lysimeters or shallow wells at different levels underlying the plots
- uptake (and analyses) of heavy metals into plant biomass including roots, stems, leaves
- some knowledge of the agricultural practices in the area, i.e., is straw used for mulch, plowed in, or is it burned off as in much small grain culture in Scandinavia

IV. CRITIQUE OF SESSION

The published work of Hinesly *et al.* and Liu-Hing *et al.* may be more useful than any of this material. It seems apparent that methodical, systematic studies addressing the deficiencies apparent in this paper (see above) and cognizant of the area agricultural practices need to be carried out. Further, such studies must address the specific problems of crop utilization as well, i.e., metals may not concentrate into grains at dangerous levels for hog-feeding, but what if the whole plant is used for ensilage, or if the entire plant is allowed to return to the soil. As an example of the latter, it has been proposed that primary sludges be composted with such waste fibrous materials as sawdust or peanut shells for agricultural use. It is critical that we know the metal content of "non-useful" portions of the plant biomass in order to ascertain the ultimate biological route and destination of heavy metals added to agricultural soils via sludges.

If there really is interest in knowing how cadmium becomes inaccessible to plants over a period of time (see Hinesly *et al.* and this paper) rather than a desire to speculate in the absence of available data, there are ample precedents in the literature on mercury methylation (largely by microorganisms according to Colwell and her co-workers) to suggest that it is time to initiate studies on the role of soil microbiota in rendering heavy metals accessible or non-accessible to plants.

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: A
Time: 2:45 to 4:45 pm

B. Workshop - Problems in the Application and Development of New Technologies

Convener: A. W. Breidenbach (USA)
Speakers: J. Bernard (France), P. E. Odendaal (South Africa), B. Berger (USA) for S. Iwai (Japan)

II. REVIEWER

A. Name: Thomas H. Goodgame

B. Position and Affiliation: Director, Corporate Environmental Control
Whirlpool Corporation
Elisha Gray II Research and Engineering Center
Benton Harbor, MI

III. REVIEW OF SESSION

As this session was a workshop, the formal papers that were presented were more for the purpose of introducing an area of discussion, rather than for the presentation of research results.

A.1 Breidenbach (USA) indicated that workshops at this Conference were the result of expressed desires at previous IAWPR meetings to allow time for discussion by all the participants. This is the first of two workshops to attempt to meet this expressed need.

Purpose of this workshop was to promote informal discussion of the subject of the workshop, and to identify areas for further discussion and/or investigation. Authors are to highlight problems in the development and transfer of technology in each area they discuss.

A.2 Bernard (France), in his presentation on physical-chemical treatment of municipal wastewater, discussed the methods of treatment used in France and some nearby European countries for the flocculation of suspended solids in municipal wastewater. This was the only aspect of physical-chemical treatment with which he dealt.

In France, flocculation by physical-chemical treatment is used differently than in the U.S. In the U.S., this treatment is used to reduce the suspended solids in, and to treat, the clarifier overflow. In France, chemical flocculation is used on the raw water. A number of reasons were given for this difference (such as phosphorus elimination,

elimination of dissolved materials for ocean discharge, rapid population turnover in tourist areas, and the dilution effects in winter resorts) which did not appear to me to answer the question -- why the difference.

He then posed four points, or questions, for further discussion:

1. What parameters should be used in chemical flocculation?
2. What are most effective rapid separation processes? For example, plate type units or the use of flotation?
3. Sludges - chemical flocculation gives heavier sludges, and these will usually contain more of the metal content of the wastewater. If this is done with lime, can the lime values be recovered?
4. Color and odor in the discharge can be a problem. These are usually caused by lack of oxygen in the filter bed.

A.3 Odendaal (South Africa), in his talk on wastewater technology transfer: selected case studies and strategies in South Africa, discussed the strategy followed in South Africa in several wastewater reclamation projects for the promotion of technology transfer from research to actual use. The main points that were covered were that the research must have well defined needs, and the users must be involved in the program in all stages. The following paragraphs emphasize those areas which are of particular interest to us. (The individual case studies reported upon are not discussed.)

The major difficulty in the transfer of technology is that application is usually sought after the research has been completed. The development and application of new technology will be better if technology transfer is intentionally a part of the research and development program. The research and development must be pointed toward well defined needs of specific users and these users must be included in the research and development program. This process bridges the gap between the researcher and the user, and most importantly - in my opinion - it reduces the perceived risk for the user through full familiarity with the research and any pilot plant development.

In South Africa, projects are usually handled through a R&D committee for the particular problem area, this committee being formed by the Water Research Commission. Mr. Odendaal indicated the importance of 1) clearly identifying needs, 2) involvement of user agency, and 3) purposely involving the responsible agency. He indicated the strong usefulness of trade associations in implementing programs of this sort.

A.4 Berger (USA, substituting for Iwai) reviewed the six points which Iwai had made in his paper on anticipation of new technologies for handling and disposal of sludges. These were in the form of questions.

1. How can rate of sludge production from municipal sewage treatment be reduced? Research is needed to determine quantities produced and new processes which will produce less sludge should be worked on.

2. How should sewage sludge be conditioned? The methods used in Japan were described.

3. How does Japan deal with collected night soil and septic tank sludge? Some 1186 plants have been built to specifically handle these materials. These appear to be standard biological plants except that separated liquor from the primary processes is diluted 20 times with fresh water before being subjected to biological action.

4. How is sludge ultimately disposed of? Of most interest to Iwai was agricultural use, even though this use is declining in Japan.

5. What is the basis of design of fluidized bed sludge incinerators? Professor Iwai suggested that incineration is the way of the future in Japan, thus the need for the process.

6. How are toxic and hazardous substances in sludges handled? The USA and Sweden are attempting to control them at the source. Industrial sludges which are contaminated should be kept separate and carefully controlled. Where recovery is not practical, stabilization and solidification are used.

A.5 Breidenbach (USA), in his presentation on monitoring strategies and systems for the assessment of effectiveness of water pollution control technology, reviewed the history of water pollution control in the USA, with particular emphasis on the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500) and the Clean Water Act of 1977 (PL 95-217). This was useful to non-USA participants but added little to the discussion for those of us who are intimately familiar with these two pieces of federal legislation.

B. As this was a workshop, there was no prepared discussion as such.

C. Floor Discussions

C.1 Chalmers (UK) posed to questions. To Breidenbach he asked, what problems need to be solved? The response was a) the purification of water, and b) the solids to be dealt with.

To Odendaal he asked, how do you make your research programs relevant, and how do you avoid duplication? The response was that the first was self-evident; the second involves the use of computers, consultants and conferences.

C.2 Idelovitch (Israel) described some of the problems existing in Israel and what is being done about them. He then proposed several questions for the panel:

1. Can physical/chemical treatment produce the same quality effluent as biological/chemical treatment? Answer - No.

2. Can oxidation pond effluent be reclaimed with suitable treatment? Answer - Yes.

3. Should precipitation be used before or after biological treatment? Answer - After.

4. Is source control a sufficient means for control of heavy metals? Answer - No.

5. Should groundwater recharge be used for water and wastewater reclamation? Answer - Yes.

Bernard responded that he completely agreed, particular with "1".

C.3 Warmby (Sweden) indicated that we do not know enough about the effluents we produce. The conventional parameters, i.e., COD, BOD, suspended solids, etc., are not enough. We should be focusing on the long term nonreversible effects. He also indicated his belief that many compounds have no "zero effect" level. Ability to analyze for trace substances needs to be improved. Response by Breidenbach indicated that our present analytical abilities now outdistance our ability to control discharges.

C.4 Hahn (Germany) indicated that a small wastewater treatment plant had produced sludge which was used in vineyards when the plant was producing an effluent with 125 mg/ℓ of BOD and 150 mg/ℓ of suspended solids. This was improved to 25 and 30 mg/ℓ, respectively, by use of the coagulants. However, bad publicity caused the agricultural users to refuse the sludge. Also in Germany, there are problems with operating costs as opposed to capital expenditures, though there is now an industrial fee which lessens this problem.

C.5 Viitasolo (Finland), in response to some earlier comments, indicated that there had been no distinguishable difference between the sludges produced in the mechanical/biological treatment and that produced using mechanical/biological/chemical treatment for the control of phosphorus. In this case, ferrous iron was used. The dried sludge contained 3.5 percent Fe.

C.6 Jones (Canada) indicated that the problem is one of motivation of those who have to implement the new technology. This is not necessarily bad, but it does affect and inhibit the motivation of civil servants, consultants, industry and municipalities for the innovative use of new technology.

C.7 Stone (USA) asked the panel to address themselves to what the future problems are, particularly in public health and environmental matters.

He also asked that standards for innovation be results rather than procedures. This has worked in the past and should in the future. Odendaal responded that results should be the measure of innovation. Then, in some cases, industry cooperation can be had for the asking, e.g., shift from hard to soft detergents. Berger indicated that we now treat water to protect fish, not humans. He further indicated that innovation is not costly if somebody else puts up the money.

C.8 Dean (Denmark) indicated we need to re-evaluate technology, and then posed other questions. Are phosphates bad? Not if you want to grow something in the water. Why eliminate phosphate discharges into the ocean where they supply nutrients, which contribute to added protection of fish? He also pointed out that phosphate bans in detergents do no good in areas where most of the phosphates are coming from agriculture. He also indicated in response to an earlier speaker that there is a "zero effect" level for most substances. His real question was, how do you change a regulation banning phosphates in detergents when phosphates in detergents are not the problem?

C.9 Jenkins (UK) indicated that empirical methods are being used and have been used in the past for the development of practically all the wastewater treatment processes we use today. There is a need for both rapid methods of analysis for chemical substances and also a rapid method for determining what their effects are. This applies particularly to the synthetic organic chemicals. Environmental standards are not enough - there must be control at the source.

C.10 Crouzet (France) indicated that many of the problems are technological. Some plants do not operate as they should, but create no problems. On the other hand, dischargers into small rivers need very reliable plants that can be operated at the local level. At the industrial level, many metal working plants in France discharge without any pretreatment. Yet, papermakers decided to evaporate and then incinerate the resulting liquor. There are also psychological obstacles to the utilization of sludge for agricultural purposes. The response by Bernard indicated that the logical applications of new procedures are needed, but that there is inertia not to do something new.

C.11 Pomery (USA) posed the question, will new methods of sludge disposal have to be developed because of heavy metals in sludge? One previous paper said no. Ocean disposal appears to be an excellent method for cities such as Los Angeles. So, is anything new really needed? The panel responses indicated that there were new things needed, but did not elaborate further.

C.12 Basol (France) indicated in response to earlier discussion that it has been established that heavy metals in industrial sludge transfers to plants. How this occurs, we do not know. He concurred that municipal sludges have never been shown to be detrimental in agricultural usage.

IV. CRITIQUE OF SESSION

There was a great deal of interest in this session, as indicated by the fact that the hall was still full when the Chairman closed the session at 5:00 o'clock - some 15 minutes later than it was due to end. There was participation by the group present.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION CONTROL ACTIVITIES

Bernard pointed up some areas where research is still needed, for example, the most effective high rate processes.

The strategy proposed by Odendaal for the rapid transfer and application of technology is worthy of study and implementation. It would appear that this would require some adjustments in how projects are developed and implemented by agencies such as the U.S. Environmental Protection Agency. This is certainly an obstacle, but not an unsurmountable one.

I think it is significant that in a group of this size, there was little disagreement. With the possible exception of the "zero effect level" and a couple of minor things, there was general agreement. Some important points made by discussors from the floor were, 1) there is a great need for some method to encourage innovative technology, and 2) the things that have been tried so far have not worked, except for the success reported by Odendaal.

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: B
Time: 2:00 to 4:15 pm

B. Theme of Session: Indicator Organisms in Wastewater and in Urban Waterways

II. REVIEWER

A. Name: Gabriel Bitton

B. Position and Affiliation: Associate Professor
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University of Florida
Gainesville, FL

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 23: "Microbiological Quality Indicators for Routine Monitoring of Wastewater Reclamation Systems," by W. O. K. Grabow, B. W. Bateman, J. S. Burger (South Africa)

This paper was concerned with a search for the most reliable microbial indicators for assessing the efficiency of two wastewater reclamation plants: Stander (Pretoria, South Africa) and Windhoek (South West Africa) plants. In both plants, only the units which play a role in the activation or removal of microorganisms have been considered: lime treatment (pH = 11.2 for 50 min), storage in an equalization basin (pH = 10.7 for 10 hr), rapid sand filtration, chlorination (2 mg/ℓ free chlorine for 2 hr), activated carbon treatment and final chlorination (2 mg/ℓ free chlorine). Water samples were analyzed for total bacteria, total coliforms, enterococci, *Clostridium perfringens*, *S. aureus*, *P. aeruginosa*, coliphages and enteric viruses. Enteric viruses were found to be the most sensitive to lime treatment and their numbers were 50-fold lower than those of coliphages. The total bacterial count increased during quality equalization, sand filtration and activated carbon treatment. This increased the value of this group for monitoring the efficiency of subsequent units. It was concluded that the total plate count was the most sensitive indicator of the efficiency of wastewater reclamation plants, particularly during the final disinfection step. Coliphages and enteric viruses were of minor importance in the monitoring of plant efficiency. During a 7 year study the authors found that the quality of reclaimed water was equivalent or even better than that of conventional supplies.

A.2 Paper No. 25: "Further Studies in Bifidobacteria as Indicators of Faecal Pollution in Water," by L. M. Evison, S. Morgan (UK)

This paper described the distribution of bifidobacteria and *E. coli* in human and animal feces. Growth response of typed cultures of bifidobacteria (*B. adolescentis*, *B. pseudolongun*, *B. bifidum*) indicate that these microorganisms are unlikely to regrow in natural waters.

A.3 Paper No. 27: "Relationship Between Indicator Organisms and Selected Pathogenic Bacteria in Urban Waterways," by V. P. Olivieri, K. Kawata, C. W. Kruse (USA)

The levels of indicator bacteria and other pathogens (*Salmonella* sp., *Pseudomonas aeruginosa*, *staphylococcus aureus*) were determined in samples of sewage, urban streams and stormwater over a 13-month period. Pathogens were consistently found in background samples, urban streams and storm runoff. Positive correlations were found between the levels of indicator and pathogenic bacteria. However, no such correlations were found in stormwater samples.

B. Prepared Discussion

B.1 Paper No. 23

Hanes (USA) questioned the use of *E. coli* B as a host bacterium for coliphage. This host does not accept male specific phages which are more resistant to chlorine than other phages. As a result, these chlorine-resistant phages may have been missed in this study. He also questioned the technique used to isolate *Clostridium perfringens*. Other bacteria will grow on the medium used when the sample is heated at 65°C for 15 min. He suggested that a better isolation technique is now available and is being published by Cabelli and his collaborators in the USA. Interest was expressed in epidemiological data that have not been discussed by the authors. The Windhoek wastewater reclamation plant presents a unique opportunity for such a study (mild symptoms as well as the commonly reported diseases associated with drinking water). It was noted that the growth of certain microbiological indicators in carbon filters was particularly useful in the selection of these indicators for drinking water quality. The discusser also suggested a study on the fate of trace organics in wastewater reclamation.

B.2 Paper No. 25

Grabow (South Africa) listed the properties of an ideal indicator of fecal pollution and noted that bifidobacteria conformed to some of these properties; they are highly specific for feces, they occur in high numbers in water but do not multiply there, and, finally, they are not pathogenic to man. However, they have two drawbacks:

1. The detection method is not that simple. The method selects only for those bacteria which can grow on arabinose and three out of five species

of bifidobacteria do not grow on arabinose. Furthermore, the medium supports the growth of a number of contaminants such as lactobacilli. We need to develop a simple method for the detection of bifidobacteria.

2. Resistance of bifidobacteria to the water environment -- a table shown by the author clearly indicates that bifidobacteria are less resistant to water purification processes than fecal coliforms.

Grabow questioned the use of the term E. *coli*. The statement that E. *coli* regrows in water is not altogether true because a member of the fecal coliform group, E. *coli* type 1, does not regrow in water. This particular bacterium can be easily detected by simple methods.

Since particular indicators should be used for particular purposes, Grabow asked whether bifidobacteria would be useful in indicating the quality of certain types of waters (e.g., drinking water, recreational water).

B.3 Paper No. 27

Parker (Australia) noted that the authors have presented a mass of data adequate for statistical analysis. The authors have shown a significant level of pollution in both stream and storm waters with correlations between indicators and pathogens for stream and background sources but not for storm water. He asked whether the results influenced by specific situations where the bleeders were in operation could be related to changes in bacterial counts. He pointed out that there was a possibility of increased bacterial counts in stormwater drains due to discharge of air valves. He also wondered whether discharges from other sources (septic tanks, flow from non-sewered houses) had any bearing on the results reported.

Parker pointed out that the degree of pollution observed would suggest that it was not necessary to go into details with regard to bacteriological examination to realize the obvious sources of microorganisms but that chemical analysis for ammonia, BOD and COD would have been sufficient to track down the sources of these flows.

C. Floor Discussions

C.1 Paper No. 23

Idelovitch (Israel) talked about the desperate attempts around the world, over the last few years, to find or even "invent" microbial indicators of fecal pollution. He reported a suggestion that man was the only suitable indicator of reclaimed water quality for both microbiological and chemical parameters. He said that health authorities over-emphasize the question of viruses in water. In the Tel Aviv Reclamation Plant only one virus was found in a 500-ℓ sample while none was found in routine analysis of 10-ℓ samples. He questioned the exclusion of *E. coli* as a recommended parameter and asked the author to comment on coliform analysis. He further stated that if, during lime treatment, the pH was increased to 11.5 and the detention time was longer than 1 hr, the microbiological quality of the water would be considerably improved.

Bitton (USA) questioned the technique for enteric virus concentration, particularly the amount of water processed (10 ℓ). He stated that there are now good concentration techniques (membrane adsorption-elution concepts) that can handle larger ($\approx$ 400 ℓ) volumes of water. Bitton also asked if the reported increase of coliphages during quality equalization and sand filtration was significant. If so, were the conditions (e.g., temperature) in these unit processes suitable for phage multiplication. He wondered whether 10 mℓ were sufficient for phage assay and proposed to find a suitable technique for phage concentration.

Ramadan (Egypt) stated that lime treatment (highly alkaline conditions) was the major step involved in the reduction of microorganisms. He indicated that 2 mg/ℓ of chlorine was not sufficient to inactivate certain viruses, especially those inside nematodes, and cysts of *Endamoeba histolytica*. He proposed that these cysts should have been taken as indicators.

Shuval (Israel) also questioned the virus concentration technique (ultrafiltration) used in this study. He added that ultrafiltration has a low virus recovery. In his laboratory the presence of one PFU (plaque forming unit) was demonstrated in 200-500 ℓ of water although no coliform was found. He added that, although river water is often of lower quality, one cannot use the standards of river water for well man-designed systems which must be completely defensible. He also proposed that alternatives to chlorination must be found. Ozone, although not free of problems, is a good viricidal agent and no known toxic substances are formed following ozonation. He also believes that the major problem in wastewater reclamation is the removal of the multitude of known and unknown chemicals. He believed that the authors have made a major contribution in proving that the reclaimed water was microbiologically safe.

Author's Reply - He agreed with Shuval that the major problem associated with wastewater reclamation is the presence of trace organics and the health hazards associated with chlorinated organics. He added that the matter is receiving a great deal of attention in South Africa but available information indicates that levels of organic matter in the water will not impose a health hazard following chlorination. However, this is difficult to prove and more research is required.

He did not agree with Hanes that male specific phages are more resistant to chlorine than other phages. He found that host bacteria that pick up male specific phages generally yield a much lower phage count than *E. coli* B.

As regards to viruses, he believes the question of viruses in water is a very controversial issue and tends to be exaggerated. He does not agree with the virus standards which have been proposed in the past, and believes that one cannot sterilize the environment and guarantee the absolute absence of viruses. As regards to virus concentration, they used 10-ℓ samples because they were easily obtainable. He agrees that there are better concentration methods that he intends to use in the future. However, he was quite convinced that their method was sufficient to prove the virological safety of the water.

Concerning the use of microbiological indicators, he believes that "one should use particular indicators for particular purposes." For example, enterococci should be used to indicate the efficiency of lime treatment. As regards to parasites (Ascaris, Taenia, E. *histolytica*), he indicated that they are efficiently removed and they make no contribution to the monitoring of wastewater reclamation processes.

C.2 Paper No. 25

Ramadan (Egypt) noted that another property of bacterial indicators is that they should survive longer than pathogens in the aquatic environment. The anaerobic growth of bifidobacteria is a disadvantage and, as a result, these bacteria will be inhibited under eutrophic conditions where there is a supersaturation with O_2. Bifidobacteria will not suit conditions in highly aerated river waters, but may be more suitable for deep well water. These bacteria must also be easily cultivated in the laboratory. The discusser added that *Clostridium perfringens* survive for long periods in sediments and therefore do not indicate whether the fecal pollution was of recent origin. He wondered whether bifidobacteria behaved similarly. Finally, he said that we need more information on the survival of bifidobacteria in various environments. This information will give some basis for reliability on these microorganisms. Therefore, based on available information, one cannot use bifidobacteria as indicator organisms at the present time.

Martin (Australia) asked whether bifidobacteria were specific for human pollution.

Author's Reply - She agreed that there are some complications in the methods used in her study. The growth medium could be made sufficiently selective to avoid subculturing. The test would consist of filtering the sample through a membrane filter and incubating in a medium which has to be prepared each time but the actual procedures involved are no more difficult than standard membrane filtration. The anaerobic incubation (use of gas pack) itself is no problem.

As regards to selectivity of the growth medium, she noted that the arabinose-positive bifidobacteria amounted to at least 7 percent whereas the arabinose-negative strains were only 1 or 2 percent. The medium was suitable for feces but not enough selective in river water (occurrence of lactobacilli contaminants). She added that this point needed further investigation.

As regards to resistance of bifidobacteria to the water environment, she recognized that these bacteria may be sensitive to dissolved O_2 and high temperatures. The matter needs more work.

She did not think that bifidobacteria could serve as indicators for drinking water.

As regards to the source of pollution, she noted that bifidobacteria are the most human specific organisms. B. *adolescentis* is always found in human feces. Bifidobacteria are the most satisfactory group for actually distinguishing the source of pollution.

C.3 Paper No. 27

Ellis (UK) commented on the levels of coliforms in waterways. He showed the results of a survey conducted during the drought of 1976 in northwest London. This survey revealed a very high level of coliform counts in waterways. This has implications for the recreational activity. He added that the receiving reservoir for this particular urban stream was closed to the public in August 1976 when *E. coli* levels reached 10^5/100 mℓ. The reservoir was eventually reopened as a result of mounting pressure from the public. Ellis pointed out that, in stormwater samples, they found little or no correlation between indicator organisms and pathogens, and little definite statistical relation between pathogen levels and hydrological indices. He wondered whether the authors had similar results. He also asked whether bird excretions accounted for the *E. coli* counts in purely separate systems.

Bitton (USA) commented on problems in methodology for the detection of bacterial pathogens, particularly *Shigella*. He asked whether fecal coliforms/fecal streptococci ratios (source of pollution) were taken into account to explain the lack of correlation between indicators and pathogens in stormwater.

Grabow (South Africa) asked the speaker to give more details concerning his findings on viruses, particularly the relationship between these agents and bacterial indicators in the stormwaters. He wondered whether the methods used were referring to Standard Methods.

Hrudey (Canada) commented on the statistical analysis. He noted that the authors used log concentration to calculate regression lines and correlation coefficients. He stated that the data should be log normal in distribution. Otherwise, the test of significance does not have any meaning.

Coin (France) pointed out that the authors did not comment on the sanitary significance of their work. He asked whether the bacteriological determinations in their work were of interest to the health of the populations in contact with these waters.

Author's Reply - As regards to bleeders' (sewage overflow) influence, Olivieri pointed out that in urban areas the situation is very complex and that it is difficult to keep track of what is going on. Regarding the influence of air valves, no work has been undertaken by the Johns Hopkins group. He added that the purpose of their study was not to find out the source of flows but merely to evaluate the levels of pathogens since there was little work done on this topic. He also pointed out that money could be better spent for correcting the minor problems in sewer systems.

He agreed with Bitton that the methods used for determining the levels of pathogens are just beginning to come about. The lack of refinements in the methods are due to the fact that we are asking too much from the enrichment media. Experiments with seeded *Salmonella* have shown that the procedure breaks down in the enrichment medium. He felt that the usefulness of FC/FS ratios is rather limited and that they would apply only to recent contamination.

In response to Grabow's questions, the speaker said that they have the virus data but that the correlations obtained were not very good. He added that all the methods used, except *Salmonella*, were performed according to Standard Methods. He noted that they experienced some problems with *Staphylococcus aureus*. These problems were solved by incorporating Na azide in the medium according to a recently published method.

As regards to statistical analysis, he believed that the data were log normal.

As regards to the public health implications raised by Coin, Olivieri pointed out that the water in the urban streams in Baltimore is not consumed and it flows into the Chesapeake Bay.

IV. CRITIQUE OF SESSION

Paper No. 23 covers the very important topic of wastewater reclamation and reuse. The material was original, particularly to those who did not attend the IAWPR Conference in Johannesburg in June 1977. Most of the discussers came from countries (South Africa, USA, Israel) which have done pioneering work in wastewater reclamation. Although there were some questions about methodology (e.g., concentration techniques), the authors made a major contribution in demonstrating that the microbiological aspect of wastewater reclamation was of minor significance as compared to the chemical aspect (e.g., chlorinated organics). However, the paper would have been strengthened if some epidemiological data were included or at least mentioned.

In Paper No. 25, the authors have presented an interesting study on the use of bifidobacteria as indicators of fecal pollution. However, the methods used are complex and need to be as simple as those used for the detection of the standard indicator organisms (total and fecal coliforms, fecal streptococci). Furthermore, this reviewer agrees with the discussers that bifidobacteria have a major drawback; that is, their sensitivity to dissolved oxygen. Another drawback is their low survival in the extraenteral environment. Therefore, this reviewer encourages more studies on the survival of bifidobacteria under various environmental conditions.

Paper No. 27 brings some very useful data on the occurrence of pathogenic bacteria (*Salmonella* sp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*) in urban waters. These data were badly needed since most previous studies have dealt with only indicator bacteria. This study brings to the surface the problem of methodology for the detection of pathogenic bacteria. This reviewer feels that some virus data should have been included in the study, especially since these data have been included in a previous report to EPA.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Wastewater reclamation is becoming a very important research topic, especially in the USA where some states are experiencing water shortages (California). It is hoped that more studies will be undertaken in the U.S. on the fate of trace organics in wastewater reclamation plants and on the epidemiological aspects of the system.

In the area of indicator organisms, we badly need indicators for viruses. The detection and assay of viruses is time consuming and expensive. The reviewer wishes that more data be obtained on the behavior of bacterial phages in various environmental samples. This type of research has already been started in Israel (Y. Kott's lab) and in South Africa (W. O. K. Grabow's lab).

I. SESSION

A. Day: Tuesday, June 13, 1978
Hall: C
Time: 2:00 to 5:00 pm

B. Theme of Session: Uptake, Accumulation and Release of Mercury, Heavy Metals and Petroleum Hydrocarbons in Fresh and Saline Waters

II. REVIEWER

A. Name: Frederick G. Pohland

B. Position and Affiliation: Professor, School of Civil Engineering
Georgia Institute of Technology
Atlanta, GA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 24: "The Role of Sediments on Mercury Transport (Total and Methyl) in a River System," by A. Kudo, D. R. Miller, H. Akagi, D. C. Mortimer, A. S. DeFreitas, H. Nagase, D. R. Townsend, R. G. Warnock (Canada)

The paper was concerned with the fate of total- and methylmercury in a 4.9 km reach of the Ottawa River, 1.6 km downstream from Ottawa, Canada. In this 5-year study, an attempt was made to determine the relative significance of bed sediments and their movement. From an analysis of the data as well as from laboratory flume studies, it was concluded that most (97 percent) of the mercury resided in bed sediments, that bed sediment movement had little effect on the movement of mercury downstream, that biomass contains an insignificant portion, and that the primary transport vehicles are the suspended sediments (58 percent) and water (41 percent).

To place the results in proper perspective, it is necessary to summarize the conditions of the study. The reach of river under consideration has a variety of uses - recreation, water supply, log-driving and waste effluent discharge from municipalities and industry, mainly pulp and paper. Extensive sludge deposits from the latter industry have become an integral part of the total sediment complex for over 100 years. The mean flow rate has varied from approximately 1000 m^3/sec (winter) to 4000 m^3/sec (spring) with a maximum mean velocity at flood flow (spring) of 270 cm/sec. This would cause bulk transport of bed sediments during flood periods; a bed-load of 400,000 kg/day was indicated. On the average, the study section is covered with ice about 3 months, i.e., it is very cold during the long winter (-29.5°C average 75-yr minimum) and hot during the short summer (33.5°C 75-yr maximum).

Water in the study section was about 21 billion kg being replaced 7.8 times per day. The average active depth of bed sediments was estimated at 7.1 cm and contained at the surface 70 percent sand, 27 percent woodchips and 3 percent clay. Aquatic plants (55 total species) grew in a 5 percent area of the study section with productivity estimated at about 450,000 kg/yr wet with an additional 635,000 kg estimated as carry-over to the next year through winter as roots and hard stems. In addition to mercury analyses, other water quality parameters were measured together with analyses on bed sediments, higher aquatic plants, aquatic invertebrates and fish.

A.2 Paper No. 26: "The Uptake and Release of Petroleum Hydrocarbons by the Marine Mussel *Mytilus edulis*," by N. Hansen, V. B. Jensen, H. Appelquist, E. Mørch (Denmark)

The paper was concerned with the uptake and release of four radiolabelled hydrocarbons by the blue mussel, *Mytilus edulis*, in seawater solutions. The specific objectives were to determine rate and extent of accumulation, influence of hydrocarbon level on accumulation, and retention of hydrocarbons after transfer to clean seawater. The test hydrocarbons included (methyl-^{14}C) toluene at 50 and 500 μCi/mℓ, (1-^{14}C) naphthalene at 3.67 mCi/mmol, (9-^{14}C) phenanthrene at 11.3 mCi/mmol, and n-(1-^{14}C) hexadene at 54 mCi/mmol. The test mussels, varying from 3 to 4 cm in length, were collected from unpolluted waters and were gradually acclimatized to laboratory conditions. Studies were performed at 15°C in 20-ℓ glass aquaria containing the test solution and 70 to 80 mussels. There was no feeding or circulation during exposure and the aquaria were covered with a minimum gas phase to prevent evaporation of the hydrocarbon. After 8 hr of exposure, the hydrocarbon solution was replaced by clean seawater which was aerated and continuously recirculated at about 1.5 ℓ/min through a granular activated carbon filter. Scintillation analyses for ^{14}C were conducted on the water and soft parts of the mussel after homogenizing, washing with 80 percent ethanol, and extracting with hexane. Pentane-extractable lipids were also determined to permit analysis in terms of lipid content.

Results indicated that the aromatic hydrocarbons were rapidly accumulated with bioaccumulation factors of about 4, 40 and >70 for toluene, naphthalene and phenanthrene, respectively. These factors were found to be independent of the water concentration level and when the mussels were transferred to clean seawater, toluene and naphthalene were released very rapidly and phenanthrene more slowly. In contrast, hexadecane was taken up and released very slowly and in an 8-hr exposure the concentration in the mussel was less than the concentration in the seawater. Coefficients of variation of hydrocarbon accumulation between individual mussels were between 18 and 32 percent and uptake and release were found to be passive processes dependent on partitioning between the water and tissue lipids.

A.3 Paper No. 28: "Accumulation of Bioresistant Micropollutants in a Particular Catchment in Hungary," by P. Literáthy and F. Lászlo (Hungary)

The paper was concerned with a report on research conducted from 1973 to 1977 on the pollution of the Sajó River, the recipient Tisza River and the Kiskore Reservoir by mercury, cadmium, lead, zinc and petroleum derivatives. Heavy metals were found to accumulate in the bottom silt at low flow rates and subsequently resuspended and transported during flood discharges. Heavy metal pollution was determined for the <25 μm, 25-50 μm and >50 μm fractions by settling the bottom silt. About 80 percent of the Hg and Pb were found to be present in the <25 μm fraction, about 80 percent of the Cd in the 25-50 μm fraction, and the greater part of the Zn in the >50 μm fraction. It was concluded, therefore, that since Hg in contrast to Cd is more susceptible to adsorption on larger particles of silt, differentiation of size fractions is necessary in order to properly assess distribution of heavy metal pollutants.

Selective measurement of polycyclic aromatic hydrocarbons was also of prime interest and results indicated that amounts extracted with benzene from the bottom sediments were bioresistant and therefore increased in relative concentration with distance from the polluting source. Over the river section considered, the concentration of 3,4-benzpyrene and pyrene were found to range between 40 to 140 and 70 to 110 μg/kg extractable matter, respectively, downstream from pollution by petroleum derivatives.

B. Prepared Discussion

B.1 Paper No. 24

Krenkel (USA) initially posed two questions, one concerning the origin of Hg with respect to either industrial discharge or natural occurrence, the other on the significance of Hg levels in terms of potential hazards to man. He then underscored the fact that the Hg content in the Ottawa River as elsewhere has decreased and that valuable insight into the equilibrium between methyl-mercury and organic mercury and their transport mechanisms has been gained. Citing a recent report on the St. Clair River by the Canadian Ministry of Environment, it was further indicated that Hg concentrations in fish have also decreased to the U.S. Food and Drug Administration limits of 0.5 mg/ℓ or within a 5-yr interval as opposed to some previous projections of 100 to 1000 yr. Moreover, methylmercury contents in sediments were found by the authors to be three to four times higher than found elsewhere which was suspected to be a function of the sediment type and organic content.

Of more significance was the comment on choice of study site. Recognizing that Hg contamination is most prevalent in lakes and reservoirs with low flushing times, Krenkel suggested that more attention should have been given to an exhaustive analysis of the downstream impoundments where the Hg would accumulate. He further objected to the conclusion that the sediments are unimportant in Hg transport since, for example, in the TVA area, the Hg problem has been somewhat precluded by accumulation of uncontaminated sediments above underlying contaminated sediments, thereby reducing methylation rates. In this respect, an analogy was drawn between the totally hydroelectric developed Tennessee River and the Ottawa River where every dam is in the backwater of another dam. Recognizing that the colloidal clays and organic humic acids are the more important constituents in Hg transport, Krenkel proposed that these should have been measured together with plankton assays and an investigation on Hg volatilization and availability to microorganisms or for complexation with other elements such as sulfur. Such a latter association apparently precludes methylation and impacts therefore on the relative health hazard. Finally, Krenkel could not clearly relate the results of the laboratory flume investigations with the conditions in the river particularly because of the difficulty in simulating in a 9-m flume the hydromechanics and reactions occurring in a 4.9-km impoundment.

B.2 Paper No. 26

Hemens (South Africa) emphasized the importance of the authors' investigations in light of recent wrecks of oil tankers that have resulted in major oil pollution incidences in the North Sea and the English Channel and have contaminated shellfish growing areas. He particularly acknowledged the exchange equilibria between the animal's lipid materials and the surrounding seawater. However, although rapid uptake and loss of aromatics occurs during short-term exposure, he indicated that there is good evidence that hydrocarbons accumulated by bivalves during chronic exposure of one to two months are not lost so rapidly if at all. Other studies with clams have suggested that short-term and long-term retention of hydrocarbons is influenced by different lipid regions of bivalves and that nonexchangeable sites in which hydrocarbons are retained for long periods could be the same as those lipids where biosynthesized hydrocarbons have been identified and located. Therefore, Hemens recommended that, in view of the apparent persistence of some hydrocarbons and similar materials such as PCB's in shellfish for periods of several months or even years, contamination and public health aspects associated with the possibility of long- and short-term sites of hydrocarbon retention in bivalves requires more study beyond what was presented. Finally, the authors were requested to indicate whether they had investigated the long-term retention aspect and whether this aspect may not be even more important than the short-term uptake and retention and loss they had demonstrated.

B.3 Paper No. 28

Fish (UK) indicated a confirmation of the authors' results with the results of others relative to the general pattern of metal distribution in river sediments and sewage solids. He also emphasized that the Sajó River is a graphic example of gross pollution with a reservoir serving as a catchment area for many pollutants. The concentration of Cd in a tributary creek at about 1 percent was cited as an example of the magnitude of metal pollution and it was asked whether analyses for Hg, Pb and Zn not reported were available. He also asked the authors for information about accumulation of Hg and Cd in the biota of the river system and in the receiving reservoir and whether the concentration in fish exceeded WHO limits. Metal pollution was considered of greater concern than the aromatic hydrocarbons. Moreover, it was considered more appropriate to provide modal rather than average flow rates to be able to assess the effects of sediment (and metal) transport. Finally, as a water management practice, it was considered more prudent to minimize the influx of metal pollution to the river system before reservoir construction is contemplated.

C. Floor Discussions

C.1 Paper No. 24

Hahn (Germany) was also puzzled by the authors' conclusion that bed sediment transport was insignificant. He suggested that perhaps it was a problem of definition and asked for a comment on the inorganic or clay content of the sediments. In a related question, particle size distribution and specific surface information was requested. Finally, it was considered inappropriate to discuss sediment transport without mentioning flow velocities or describing the hydraulic regime. In attempting to extrapolate the authors' velocity data of 10 to 60 cm/sec to other systems, it was observed that considerable sedimentation could occur at about 10 cm/sec and instantaneous erosion at 60 to 100 cm/sec. Therefore, the low and high velocity periods should have been separated and identified to determine the actual corresponding behavior of the sediment shifts before its significance was evaluated.

Somlyody (Hungary) asked the authors to expound on their present attitude toward attempting to describe sediment motion in view of its cohesive character, to explain why Hg content of the suspended solids was independent of suspended solids itself, and whether an attempt was made to study the different biological, physical or chemical mechanisms for sorbing Hg to the sediments or suspended solids.

Author's Reply - Kudo initially called on one of his co-authors, Nagase, to discuss difficulties in analysis of methyl-mercury in natural water. It was stated that, although some reports are available, no established and acceptable analytical methods currently exist primarily because of the low concentration in the order of 1×10^{-6} mg/ℓ. However, it was acknowledged that at these levels, Hg could concentrate to 0.5 mg/ℓ in fish and that additional effort was being expended on a new analytical method. Kudo then recognized the difficulty of responding to all the questions posed in the discussion and condensing the results of a comprehensive 5-yr effort into a brief presentation. He mentioned the existence of three previous reports, the final report being available upon request to the National Research Council of Canada, Ottawa, Ontario, Canada K1A 0R6. In response to Krenkel's discussion, Kudo indicated that all the points that were introduced were discussed and argued by the professional staff

(12 scientists and/or professors in various disciplines) and that the report represented a concensus. At this point, an additional slide was introduced where an attempt was made to demonstrate the difficulty of classification of sediments which change from location to location and season to season. Recognizing these changes within the perspective of the other discussions, the author again iterated the need to compromise on interpretative analyses and finally recommended that the audience read the report and draw their own conclusions.

C.2 Paper No. 26

Ellis (UK) also emphasized the extreme importance of a long-term retention of hydrocarbons by bivalves and indicated that it is one of the emerging concerns in environmental quality. Citing a preliminary study to develop a steady-state model of hydrocarbon flux through a number of tributaries in the River Thames in North London, it was suggested that as with the Danish studies, benthic organisms and sediments contain hydrocarbon burdens of variable magnitude. Moreover, since many benthic food webs are primarily supported by particulate deposit feeders and microorganisms, filter feeding mussels are being used to accumulate and accelerate the rate of suspended sediment deposition. By holding six to seven 10-g mussels in a sealed submersible container, 200 g of sediments containing up to 10^4 mg/kg of hexadecane extractable matter could be collected in about 6 to 7 days. Relating this concentration to the benthic deposition of pollutant oil and grease residues, Ellis re-emphasized his agreement with the concept of very significant foodweb magnification in the processing of hydrocarbons. The major problem in their research approach was retaining sufficient mussels to obtain sediment for analysis since the mortality rate was extremely high.

Author's Reply - Hansen agreed with Hemens that additional studies are needed but indicated the difference between their studies and other cited investigations where natural oil was used. However, even in these studies, highest accumulations were found among the aromatic hydrocarbons and lowest among the aliphatics. The reasons for retention of certain hydrocarbons was thought attributable to high molecular weight. Finally, the author emphasized that the bioaccumulation factors under actual situations in the marine environment may differ from those determined in the laboratory since many unknown factors would influence the uptake and release processes. In addition, he did not totally agree with the comments by Ellis on foodweb magnification and maintained that most of the substances studied were not very strongly retained in the organisms.

C.3 Paper No. 28

Imhoff (Germany) commented on the use of reservoirs as an excellent tool to provide self-purification of polluted streams with regard to heavy metal-laden sediments.

Zobrist (Switzerland) emphasized the importance of sediments in determining the fate of heavy metals and requested that the authors indicate how they calculated fluxes in the river system and to explain why Cd accumulated in the sediments throughout the year.

Benedek (Hungary) chose to reply to the official discusser's (Fish) remarks concerning water management in Hungary. He indicated that there are very definite plans to dredge the river of offending sediments and emphasized the problems of metal pollution from not only industry but from non-point sources such as agricultural activities and precipitation fallout. Finally, he asked the Chairman to put on record the philosophy that the only possible way to eliminate heavy metals like Cd is to retain them at their source by changing technology and introducing other measures even if expensive. Chairman Imhoff agreed and indicated the need for stringent standards for discharge of metal pollutants.

Author's Reply - Literáthy responded to the question of accumulation of metals in biota and fish by indicating no results were available since this was the responsibility of other institutions in Hungary. Additional information was introduced to demonstrate the accumulation of Hg and Cd downstream of a metal discharge. Before a large flood flow, the sediments were high in metals; after the flood, the metals were washed out and decreased by a factor of four. Thereafter, accumulation again occurred. Moreover, since there were no fish in the Sajo River in this reach, accumulations of Cd and Hg in fish was a moot question. To the question of fluxes, mass balances were calculated from grab samples from the water body from which the sediment accumulation was determined by the difference between input and output. The continuous accumulation of Cd was determined on the basis of samples taken every week during the study period. Both metals and polycyclic aromatic hydrocarbons were considered of equal importance in terms of pollutant impact. Finally, it was conceded that although the building of a reservoir before the elimination of discharge to its backwaters may not be a universally accepted procedure, the situation in Hungary is such that dredging has been commenced and pollutional discharges are being curtailed at the same time that the reservoir is just beginning to underfill.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The session certainly focused on contemporary issues associated with metal and hydrocarbon pollutants which are of worldwide concern. Although no dramatic breakthroughs were presented, the papers certainly contributed to the reservoir of knowledge in a variety of international settings, i.e., Canada, Denmark and Hungary. Moreover, each paper reflected the culmination of some rather intense and long-term studies, reports of which are available for additional scrutiny and extrapolation within the American perspective. In each case, definite applications and analogies could be identified and the opportunities for communication with other research groups have been enhanced. With the recent interest in hydrocarbon pollution and fate of toxic materials in the U.S., this session was very timely and should serve as a catalyst to these interests both here and abroad.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: A
Time: 9:00 am to 12:30 pm

B. Theme of Session: Nutrient Removal from Wastewaters

II. REVIEWER

A. Name: Richard E. Speece

B. Position and Affiliation: Betz Chair Professor of
Environmental Engineering
Drexel University
Philadelphia, PA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 29: "The Effect of Diurnal Ammonium Load Variation on the Performance of Nitrifying Activated Sludge Processes," by W. Gujer, P. Erni (Switzerland)

Diurnal variations of wastewater flow, reduced nitrogen load, temperature, process pH, dissolved oxygen, etc. result in extreme diurnal variations of effluent ammonium concentrations. The influence of hydraulic residence time distribution, wastewater load equilibration and control procedures on the performance was found to be capable of preventing ammonium breakthrough. The ratio of the maximum to average daily ammonium load is known to be an important design parameter for nitrifying activated sludge processes because it gives an estimate of the safety factor that has to be considered in the choice of the required sludge age.

The EPA publication, "Process Design Manual for Nitrogen Control," advocates plug flow activated sludge reactors to be theoretically more efficient than CSTR reactors, but this is not necessarily true. This is where longer hydraulic residence times favorably affect dispersion of the incoming ammonium load. Also, while solids recycle is a tool in process control, solids recycle alone cannot significantly influence nitrification process performance. Storage of concentrated biomass for potential future use would be required.

In small plants (with higher ammonium variations), the optimum process configuration depends on the sludge age which will be chosen based upon effluent standards. A single CSTR is best at low sludge age whereas a "plug flow" process is best at high sludge age. For large plants (with lower ammonium variations) the difference of performance between the two reactor types is not as pronounced as theoretically projected for steady state processes.

Plug flow systems would normally result in DO limitations at the head end of the aeration tank and adversely affect nitrification. In small plants an increase in sludge age in parallel with an increase of the aeration tank volume does not bring the same advantage as an equal additional volume of side-line storage. In small plants the use of some volume for load equilibration may be more economical than a similar increase in aeration tank volume for improved process performance.

A.2 Paper No. 32: "Consistent Biological Phosphate and Nitrate Removal in an Activated Sludge Plant," by M. S. Simpkins, A. R. McLaren (South Africa)

Pilot plant studies were conducted with a treatment scheme for biological phosphate and nitrogen removal (BARDENPHO). The flow diagram incorporated 14 basins. Process efficiency as determined by the removal of P, N and COD, was given in terms of monthly average values.

At no stage was any ammonium detected in the effluent. The average concentration of total nitrogen in the effluent was 5.8 mg/ℓ of which 4.4 mg/ℓ were nitrates. Overall nitrogen removal was 80 percent. Phosphate was reduced from approximately 5 mg/ℓ to less than 1 mg/ℓ. The phosphates were removed from the reactor by means of the daily wastage of sludge.

In the activated sludge process, the biological removal of phosphorus compounds is primarily by biological uptake, while a minor fraction of phorphorus removal is by physical-chemical precipitation. Higher orthophosphate concentrations in the effluent were correlated with COD. The anaerobic release of phosphate was in direct relationship with input COD. Proportionally more COD was utilized by a higher input of nitrate, consequently the release of phosphate was poor and higher concentrations of orthophosphate were found in the effluent.

In order to induce phosphorus uptake the sludge returned to the reactor from the clarifier must undergo a period of anaerobiosis, indicated by a release of soluble phosphates. Following this the mixed liquor should undergo a period of aeration, during which the phosphates would be accepted into the bacterial mass by some means. It is not understood whether it is the release of phosphate, per se, which is a prerequisite for phosphate uptake, or whether the release indicates that a necessary conditioning environment has been established.

A.3 Paper No. 35: "Design Considerations for Integrated Nutrient Removal Systems," by P. M. Sutton, K. L. Murphy, B. E. Jank (Canada)

Pilot plant studies were conducted to gather information which could be used in the design of single or combined sludge systems for nutrient removal. Five different combined sludge process configurations were studied.

It was found that raw sewage was comparable to methanol as an organic carbon source for denitrification. Denitrification was limited unless 8 g of filterable COD was available per g of equivalent NO_3-N reduced. The location of the anoxic reactor in the post or predenitrification configuration had no influence on the nitrate removal rate under non-carbon conditions. In many cases, the organics present in the raw sewage were not in sufficient quantity to obtain complete denitrification in the anoxic reactor.

The wide variation in denitrification rates reported in the international literature may be due to the dependence on the system SRT. The observed rates generally decrease with increasing SRT. This is to be expected if denitrification is driven by endogenous respiration. The pilot plant results confirm that if a pre-anaerobic zone is created in an activated sludge system, a high degree of phosphorus removal can be attained without chemical addition.

A.4 Paper No. 38: "Alkalinity - A Neglected Parameter in Advanced Wastewater Treatment Systems," by M. Nielsen, E. Budgaard (Denmark)

A mathematical model was used to calculate the requirements for pH control when the characteristics of the raw wastewater alkalinity, nitrogen and phosphorus were known. Different combinations of biological and chemical treatment systems were considered for nitrification, denitrification and chemical addition for phosphorus removal. The model is general and can be applied to all of the most common combinations of biological and chemical processes for wastewater treatment in the pH range 6.0-8.0.

In soft water areas, where there may be problems in keeping sufficient alkalinity in a plant with nitrification, a considerable amount of alkalinity can be gained, if a denitrification stage is incorporated into the system. Also, the use of ferrous iron for phosphorus removal by simultaneous precipitation instead of alum or ferric salts can reduce or eliminate the requirement for expensive lime addition. The reason why simultaneous precipitation is always less expensive than post precipitation is that the price of ferrous salts is only half the price of alum.

In hard water areas where post precipitation is used, the introduction of nitrification in the biological process may reduce the cost of chemicals 50 percent.

B. Discussions

B.1 Paper No. 29

Picard (France) questioned if the results were a simulation of an uncontrolled process. He noted that no experimental data were reported.

The question of winter time temperature was raised with the comment that it was surprising that good nitrification was possible under winter conditions. He questioned the use of an oxygen inhibition coefficient rather than the application of a Monod type relation. It seemed to be an anomaly that at a given SRT, lowering of the HRT produced worse results.

Eckard (France) showed results of a model they had formulated based upon separate organic-N and NH_4-N. He showed graphs which demonstrated how the French model could simulate Gujer's results. A step function in ammonium loading rate caused an asymptotic decrease. Nitrate increased while TKN decreased.

White (England) emphasized that most activated sludge models do not contain a realistic model of sludge settleability. This has profound practical implications. A definite problem exists if equalization tanks are provided for ammonium load equalization. Storage results in septic wastewater which in turn results in poor settleability. In this regard White expressed his approval for the use of digester supernatant for load equalization. He pointed out that experience in England indicates that activated sludge in CSTR degrades the settleability. An anoxic zone improved settleability. White disagreed with Picard on the desired rate of sludge recycle because higher rates of recycle increase the CSTR phenomena which adversely affects settleability.

Kavanaugh (USA) introduced the perspective of a consulting engineer by stating that in actual fact, the design of activated sludge plants is based upon previous experience and state standards. There is very little time available during the design period to use sophisticated models. He posed the question, "Could Gujer's model be used for design in place of state standards?" He made the observation that these models are a rationalization of safety factors now incorporated into state standards.

Ford (USA) made the observation that in one and even two sludge systems MLSS, MLVSS, HRT and SRT are very general factors which may have no value. The fundamental consideration is the concentration of nitrifiers. He observed that there are techniques for observing the oxygen demand of nitrifiers.

Author's Reply - It was emphasized that this whole study was theoretical - not experimental. It was specifically directed toward the problems encountered by the city of Zurich. Space is severely limited. These simulations were meant to give a "feel" for the process under dynamic conditions and were never intended to provide actual design criteria. Gujer stated that he knew of no model which adequately incorporated the influence of DO in nitrification. He stated that TKN is an important factor, but then heterotrophs would be involved and the model could not handle heterotrophs.

B.2 Paper No. 32

Nichols (South Africa), in his prepared discussion of Paper No. 32, presented their most recent hypothesis on the mechanism of biological phosphorus removal. Phosphorus is transported across the cell wall and deposited inside the cell as a polyphosphate. Obligate aerobes all accumulate phosphorus as a polyphosphate and carbon as polyhydroxybutyrate. Under anaerobic conditions, the cell needs ATP to pump phosphorus into the cell. However, since they are obligate aerobes, no ATP is available under anaerobic conditions. Therefore, polyhydroxybutyrate is utilized under anaerobic conditions which represent a stress. Bacterial staining with Sudan Black indicated loss of polyhydroxybutyrate at the end of the plant and high polyphosphate levels. A 150×10^6 ℓ/day plant was commissioned three weeks ago in South Africa utilizing flow equalization.

Sutton (Canada) stated that pilot plant evaluation of the process could not achieve successful phosphorus removal. He stated that poor phosphorus removal reported by the authors was due to low COD which resulted in low phosphorus incorporation due to bacterial synthesis. Sutton posed the question, "Is total absence of nitrate required to get true conditions for phosphorus removal?"

Stone (USA) pointed out that biological removal of phosphorus was first observed in the San Antonio and Milwaukee plants. It first appeared that under growth phase, phosphorus was removed. Then under stress phosphorus was released. He questioned the ultimate disposal of sludge incorporating the phosphorus.

Author's Reply - There is a difference between anaerobic and anoxic. The presence of nitrate, even though no DO is present, prevents phosphate release. The sludge recycle rate was 100 percent Q and the MLSS recycle rate was 200 percent Q. A very important consideration is the critical ratio of COD/TKN/P. To get efficient P removal, first it was necessary to get very good nitrification and denitrification.

B.3 Paper No. 35

Matsche (Austria) pointed out that increased aeration in a Pasveer ditch reduced denitrification. They found that denitrification is not a function of the nitrate concentration, just MLSS. However, for design it is necessary to use a unit denitrification rate. Approximately 70 to 80 percent of the biomass is able to denitrify. Therefore, the oxygen uptake rate can be reduced. The concentration and health of the biomass as well as the carbon source affect denitrification. Matsche emphasized that methanol has many disadvantages. It has a high cost, increases sludge production and resultant sludge disposal problems. There is also a crucial problem in control of the methanol feed rate. Overfeeding results in organic pollution of the effluent. Underfeeding results in incomplete denitrification. Automatic feeding based upon feedback of the instantaneous nitrate concentration and flow rate has not been developed. By comparison anoxic conditions are easy to control.

Harremöes (Denmark) questioned the validity of "anoxic SRT." He felt this was not a valid concept since the biomass is predominately facultative.

Gujer (Switzerland) noted that of the 100 data points, the SRT was as high as 16 days. He surmised SRT was calculated on a 1 day basis and stated that SRT should be calculated over at least 1 SRT.

Marais (South Africa) noted that kinetic constants were based upon MLSS and observed that this would be quite dependent on SRT. At 20 to 50 days SRT, the active fraction of the biomass is only about half of the total. He stated that the authors should have used the active biomass fraction and hypothesized that if they had done so the kinetic coefficients would have been constant. An effect of the anoxic period is that it reduces the endogenous respiration and therefore results in higher sludge yields. Marais felt that if the anoxic period was in excess of 30 percent of the total, nitrification would cease. It also may depend on alkalinity, because if anything goes wrong with the denitrification step, the pH may drop to 5.0 or 6.0.

Simpkins (South Africa) requested a clarification of terms. Does the author define endogenous respiration as feeding on stored material or death, lysis and release of cell contents to the liquid?

Author's Reply - Methanol addition was required in the denitrification step. If methanol addition ceased, denitrification decreased. Apparently the raw sewage carbon was inadequate to drive the denitrification step at maximum rate. Sutton stated that Marais' method of measuring active solids was used. However, it is too tedious to be incorporated into routine use.

B.4 Paper No. 38

Jenkins (USA), in a submitted discussion of the paper, questioned whether CO_2 was vented in the alkalinity determination. He criticized the authors for referring to hardness in that hardness has nothing to do with alkalinity. Only pH is significant when adding Fe and Al. It does not help to restore alkalinity in the denitrification basin following nitrification. The pH in contact with the nitrifiers would still adversely affect nitrification. Denitrification must occur simultaneously in the nitrification basin if its contribution of alkalinity is to benefit the pH for nitrification.

Gujer (Switzerland) stated that he could not accept the title of the authors' paper since there are numerous references to the significant role of alkalinity in the literature. Gujer stated there was an error in the theoretical equation for alkalinity in that it omitted hydrogen phosphate and metal hydroxides. He observed that high aeration strips CO_2 and helps raise the pH. He also showed a slide of diurnal pH, inlet and outlet alkalinity.

Marais (South Africa) stated that he felt there was little consequence in the mistake in the theoretical equation. He emphasized that only alkalinity was considered when pH is of prime interest. Marais made reference to the carbonate system and said that it could be defined by any two points: dissolved CO_2 and alkalinity, or equilibrium carbonate and net strong acid. He illustrated his point with a slide figure of the carbonate system.

Pohland (USA) pointed out that at lower pH values, organic acids contribute to the alkalinity.

Ferguson (USA) observed that since the stoichiometry of the alkalinity consumption is well understood, it is not surprising that the model predicted the actual situations quite well. He also emphasized again that pH is of central importance. Ferguson noted that the pH objectives of the processes are not well understood however. For instance, the pH range for phosphate precipitation with alum is somewhere in the range of 5.0 to 6.0. For phosphate precipitation with iron, the range is 4.5 to 5.5. A pH of less than 7.0 inhibits nitrification. However, a pH as low as 6.0 is satisfactory at long SRT values. He also noted that the dissolved CO_2 concentration in conventional activated sludge is low. However, the dissolved CO_2 is much higher in oxygen activated sludge and also with alum precipitation of phosphate. For low phosphate residual, 25 mg/ℓ of alkalinity must be maintained. For nitrification 15 to 25 mg/ℓ is required. Ferguson noted that the empirical rules suggested by the authors were not adequate to predict the above alkalinity values.

Shelef (Israel) observed that the important area of lime treatment was omitted by the authors.

Molof (USA) made an observation on stream nitrification that it could satisfactorily proceed in a pH range of 6.0 to 8.0.

Author's Reply - The author pointed out that the purpose of the paper was to present a short quick method for design engineers to use to check if the alkalinity was sufficient to sustain the process. He also noted that CO_2 does not affect alkalinity-only buffer capacity. The author made reference to two sludge nitrification-denitrification systems and stated that pH problems are minimized in one sludge system with simultaneous nitrification-denitrification. He said he had also observed that the pH varied in a constant alkalinity system and deduced this was due to CO_2 loss.

IV. CRITIQUE OF SESSION

The financial burden of chemical costs for N and P removal is an international problem. One is led to the conclusion that this financial burden is almost to the point of becoming unbearable even to the relatively advanced nations. It has forced all countries to explore the possibilities to achieve N and P removal without chemical addition. Therefor, the prospect of achieving N and P removal solely by biological means without supplemental chemical addition is most attractive. These research efforts are concentrated mainly in western Europe and North America. The absence of Japanese research in this area is noteworthy. This reviewer has visited Japanese wastewater treatment and research installations and has come to the conclusion that they are willing to bear greater wastewater treatment costs due to the severity of some of their pollution problems and the population density of their major metropolitan areas. The intense South African research effort is prompted by the severe water shortage in that country and the fact that many of their industrialized centers are located far inland. This increases the opportunity for water impoundment and subsequent eutrophication as the water flows to the sea.

Numerous references were made to full scale plants that are already operating or under construction. Nutrient removal appears to have more prototype installations than activated carbon plants, indicating that more countries are committed to N and P removal than to tertiary carbon removal. (One point was made that Europeans either love or hate activated carbon.) A cursory evaluation of the topics presented at this conference leads this reviewer to conclude that nutrient aspects of wastewater treatment were the dominant considerations of the conference.

The interrelation of the various treatment unit operations is strongly manifest. Phosphorus removal was dependent on complete nitrification. Effluent filtration was critical to removal of phosphate precipitates to achieve low effluent phosphorus. Coagulation was critical to effective filtration. Adequate aeration capacity was crucial for effective nitrification. Equalization was crucial for preventing diurnal ammonium breakthrough. The method of sludge disposal was crucial to prevention of phosphorus from re-entrance into the aquatic ecosystem.

The views of the conference participants were strongly flavored by their home country situation. Water rich countries (such as Scandanavia) with eutrophication problems were strong on nutrient removal. Water poor countries (such as Israel) which had to rely heavily upon water reuse advocated activated carbon tertiary treatment of wastewater regardless of the cost.

Some fundamental inconsistencies must be resolved in biological systems for the removal of N and P. The environmental conditions required to achieve biological removal of phosphorus are ill defined. The Canadians report low P removals and the South Africans report high P removals.

The process configurations utilized for nitrification-denitrification are quite varied and appear to be subject to considerable "personal" choice. Some advocate one sludge system while others advocate two sludge systems. In view of the common difficulty reported, i.e., nitrification under winter conditions, it is surprising that fixed film systems are not advocated more for nitrification of activated sludge effluents. Suspended growth systems are subject to continual wasting as effluent suspended solids which are not removed by secondary clarifiers. This makes it difficult to achieve the requisite extended SRT values required for cold weather nitrification.

On a global scale this interchange of research results has two profound effects:

1. It makes available to underdeveloped countries, design technology which will allow them to proceed faster in their water pollution abatement programs.

2. It permits the countries which are spearheading the water pollution technology effort to advance much more rapidly with a given funding level due to the mutual exchange of information, minimizing duplication of effort.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: B
Time: 9:00 am to 12:30 pm

B. Theme of Session: Estuary and Ground Water Quality Modeling and Monitoring

II. REVIEWER

A. Name: Vladimir Novotny

B. Position and Affiliation: Associate Professor
Department of Civil Engineering
Marquette University
Milwaukee, WI

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 30: "The Thames Model: An Assessment," by M. J. Barrett, B. M. Mollowney, P. Casapieri (UK)

The mathematical model of the Thames estuary was developed by the Water Pollution Research Laboratory (now the Water Research Centre, Stevenage Laboratory) in the late 1950's. The model, calibrated and verified by extensive measurements during the period from 1950 to 1961, was adopted as a basis for control of pollution by the Port of London Authority and in its latest version, is now also used as a management tool by the Thames Water Authority.

The estuary is imagined to be divided into a series of segments which oscillate upstream and downstream with the tidal velocity. The fresh water flow, which is assumed to be steady and in equilibrium with the salinity distribution, is represented by a volume flow through each segment into the one immediately downstream. It has been indicated by the authors that the "moving box" concept substantially reduces the numerical problems of the solution.

The processes which can be simulated by the model include, among others, BOD reduction and transformation; dissolved oxygen; and nitrification and denitrification. In modeling the dissolved oxygen conditions, the following observations were made:

1. The rates of oxidation of carbon compounds are proportional to their concentrations.
2. The organic nitrogen is converted to ammonia at the same rate as the carbon is oxidized.

3. The rate of oxidation of ammonia is proportional to its concentration.

4. Oxidized nitrogen is destroyed at a very slow rate, proportional to its concentration.

   When dissolved oxygen falls below 5 percent of saturation, assumptions 3 and 4 are replaced by 5 and 6 below:

5. The rate of oxidation of ammonia is initially decreased and if, despite this, the concentration of oxygen remains below 5 percent of saturation, the oxidation of ammonia ceases and oxidized nitrogen is reduced to molecular nitrogen at a rate sufficient to maintain the oxygen content at 5 percent.

6. The concentration of oxygen is allowed to fall to zero when the reserves of nitrate are exhausted.

It was also found and applied in the model that the oxidation of a wide range of wastes including sewage consists practically of two stages - fast and slow. To account for this the BOD reaction was modelled using the following relationship:

$$y = E_c [1 - (1-p) \exp(-kt) - p \exp(-kt/5)]$$

where y is the oxygen uptake in time, t; k is the standard rate constant of 0.23 day^{-1} at 20°C; p is the proportion of the organic material oxidized at the slower rate; and E_c is the ultimate BOD.

The model has been used for modeling a stretch of the Thames estuary between a point about 20 km upstream from London to the mouth of the estuary.

The observed and computed seasonal and longitudinal variations show an acceptable agreement.

B.1 Prepared Discussion

Kahn (Germany) commented that the model does not neglect hydrologic and hydraulic behavior of the system. It includes seasonal as well as spatial water quality differences. The model also enables the investigator to simulate temporal changes due to reduction or increase of pollution loadings. Although the model is simple, several other water quality parameters can be simulated and as stated by the authors the model can be used for management purposes. The questions the discusser asked the authors were as follows:

1. For what sort of management has the model been developed?

2. Is the model applicable to simulate long term ecological changes?

3. The Bod reaction contains fast and slow rate components described by the parameter p. How is this parameter determined?

4. It has been found that if the concentration of ammonia drops below 3-4 mg/ℓ, a significantly reduced transformation to NO_2^- takes place. Why is this not included in the model?

5. What sampling techniques were used for collecting the field data (i.e., grab or long term composites)?

6. Has any effect of storm water discharges been observed or modeled?

C.1 Floor Discussion

Prinz (Australia) also questioned the sampling techniques and inquired about the future of the model.

Author's Reply - Barrett pointed out that the two-stage carbonaceous BOD reaction is an empirical approximation. The parameter, p, was initially determined by laboratory long term BOD tests. The following values of the p factor were accepted:

Raw sewage - $p \simeq 0$

Biological effluents with BOD <20 mg/ℓ, $p \simeq 0.5$

Highly treated effluents and river water, $p \sim 1.0$

Industrial effluents must be individually examined. As to the ammonia conversion to nitrates, the reaction is unrestricted if DO content >5 percent of saturation and reduced when the DO is less than 5 percent of saturation. The model has been applied to other estuaries. The work on the model continues and presently two- and three-dimensional models are being developed.

Mollowney (co-author) answered questions regarding the use of the model for management purposes. The Port of London Authority has jurisdication only over the Greater London Area. The management questions studied by the model included the water quality response to various pollution inputs such as:

- present pollution input during dry seasons
- restricting pollution loads to so-called Royal Commission standards (20 mg/ℓ of BOD_5, no nitrification)
- more sophisticated effluent limitations.

The management strategies were focused on:

- effect of reducing effluent loads
- effect of cooling heated discharges from a power plant

The most effective water quality control can be achieved by the effluent load limitations. Cooling had very little effect.

A.2 Paper No. 33: "Application of a Mathematical Model to the Characterization of Dispersion Effects on Groundwater Quality," by P. Peaudecerf, J. P. Sauty (France)

The paper introduces a method of characterizing dispersion in groundwater aquifers. At first, a two-dimensional dispersion model was developed. The model describes the transfer of miscible pollutants in a uniform groundwater flow. The model then was solved for a pulse of a pollutant represented by a Dirac function. The solution was normalized and a set of dimensionless concentration C-curves drawn. The curves depend only on a dimensionless dispersion Peclet number:

$$a = \frac{u^{L}}{Dm} \simeq [X^2/\alpha_L{}^2 + Y^2/(\alpha_L \alpha_T)]^{0.5}$$

and dimensionless time coordinate

$$t_R = \frac{ut}{\alpha_L}$$

where u = velocity in the direction of flow

L = characteristic length

X = distance from injection well to an observation well (taken in the main direction of flow)

Y = transversal coordinate of the observation well from the main direction of flow

D_L = dispersion coefficient

α_L, α_T = longitudinal and transversal diffusion characteristics of the aquifer.

During the test, a tracer is injected into the injection well and the dimensionless concentration C/C_{max} is then plotted vs. actual time (hours, days, etc.). This curve is then superimposed on the dimensionless set of curves and the most representative curve is then selected. The coincidence of the experimental curve with one of the set yields the Peclet number, a, and the comparison of actual time with the dimensionless time, t_R, will yield u/α_L. In his introduction, the author discussed the problem of tracers. Many tracers such as Rhodamine can be adsorbed by soils and/or slowed down during travel. The best results were obtained with iodine 131 and tritium. In practical experiments, radial wells are best for injecting the tracer. The model does not perform well for short distances (less than 50 m). The best agreement of the experimental results with the theoretical model was obtained when the observation wells were located more than 150 m from the injection well.

The method can be applied for studying dispersion of pollutants in groundwater aquifers.

B.2 Prepared Discussion

Poeppinghaus (Germany) summarized the merits of the proposed model. First, the parameters of longitudinal and traverse dispersion in an aquifer can be determined quickly by a graphical comparison of measured curves with a set of dimensionless dispersion curves. Second, the method seems to be feasible and of a value to those studying the dispersion of pollutants in groundwater aquifers. However, there are a few drawbacks which ought to be mentioned:

1. There are difficulties in selecting proper tracers. It seems that adsorption and absorption of many tracers can grossly deviate the concentration response curves. The tracers can be adsorbed by soils and organics present in the aquifer.
2. In some instances, the flow seemed not to behave according to the model.
3. The dispersion coefficient, D_L, changes with distance and with temperature. Both effects were not included.
4. There are other mechanisms which can affect the dispersion of pollutants in the groundwater aquifers. These include, among others, biological and chemical changes during travel.

The following questions were asked by the discusser:

1. How was the relationship of the dispersion coefficient vs. temperature accounted for?
2. What was the degree of correlation between the measured and computed values?
3. Can the model also be applied to warm water discharges or liquids with other viscosity (oils)?

C.2 Floor Discussion

Edworthy (UK) noted that the thickness of the aquifer which was examined was rather thin but still there were significant differences in peak locations. Most aquifers have more than one permeability and these are not uniform. The adequacy of the approach for large-scale testing was also questioned.

Author's Reply - Ion exchange and adsorption of tracers are very difficult to measure *in situ* but some measurements can be done in laboratories. Dispersion and conversion are hydraulic properties and can be only linked to flow and are independent of other factors. Soluble substances in smaller concentrations do not change the hydraulic characteristics of the flow. The decay or transformation of pollutants can be included after a reasonable mathematical representation is included in the basic differential equations.

The best results were obtained with iodine 131, phenol and tritiated water. Rhodamine, lindane and lithium gave the poorest results due to adsorption and ion exchange of the tracers with the soil particles and organics in the aquifer. The effect of temperature was not studied. The aquifer had relatively uniform temperature throughout the year. Temperature may become significant if very deep aquifers are studied. The results on the warm water injection experiments will be published this year (1978).

As to application and extrapolation, geologists must evaluate whether the aquifer is uniform and does not change on a large scale. The measurement should be taken at longer distances, presumably more than 10 H, where H is the thickness of the aquifer. Only then will the two-dimensional assumption be satisfied.

A.3 *Paper No. 36*: "The Effects of the Disposal of Effluents and Sewage Sludge on Groundwater Quality in the Chalk of the United Kingdom," by K. J. Edworthy, W. B. Wilkison, C. P. Young (UK)

The English Chalk formation supplies 25 percent of the potable water in the United Kingdom. It also has been estimated that about 150,000 m^3/day of sewage effluents are discharged in the Chalk. In addition, 300,000 to 400,000 tons of sludge are annually used as agricultural fertilizers in the Chalk region. In the month of July, the ratio of the natural infiltration to sewage recharge approaches one.

The objectives of the study were:

- to determine the effectiveness of saturated and unsaturated zones on improving sewage effluent quality
- determine long-term effects on the aquifer
- measure effects of sewage discharges on groundwater levels and estimate the travel times
- establish aquifer management guidelines and define unsuitable areas for effluent discharges

In conclusion, the research indicated that:

1. The chemical quality of effluent water is only slightly modified during infiltration through the unsaturated zone. Most of the modification is by dilution in the saturated zone.

2. Bacteria and viruses can penetrate distances over 15 m but are absent after a distance of 100 m.

3. Groundwater quality degradation can extend to a distance of 2 km.

4. Similar conclusions can be drawn for measuring sludge.

5. Heavy metals present in the sludge are immobilized by soils and are not leached in the groundwater.

B.3 Prepared Discussion

Shuval (Israel) pointed out that land disposal systems of sludge and sewage ought to be considered as reuse systems rather than disposal systems especially when groundwater is used for water supply. The discussed system, if it were designed for water reuse, would have never been approved. Using an example from Israel, it was documented that a well located in a Chalk aquifer receiving sewage had been safe for 15 yr but during a heavy storm there was a breakthrough and an epidemic resulted from the contamination. He also pointed out the problem of nitrates in the groundwater which are already reaching the unsafe limit (10 mg/ℓ). Chalk aquifers should be considered unsafe.

C.3 Floor Discussion

Graven (South Africa) inquired whether more information on microbiological (viral) pollution was collected. He pointed out that coliforms may not be a good indicator due to a rather low survival rate. Some other microorganisms may better survive the aquifer conditions.

Vissallo (Finland) stated that the results presented in the paper agree with those observed in Finland and Sweden (Uppsala). In these aquifers, nitrates represented a risk especially to the health of infants. A question was asked whether nitrogen components were analyzed.

Montgomery (UK) pointed out that the Southern Water Authority was located mostly in the Chalk area. In this area, 12 sewage disposal works dispose directly into Chalk. The present tendency is to encourage denitrification in the aquifer. Some of the unsaturated zones in the disposal sites behave like a trickling filter; 99 percent of the total and fecal coliforms are removed in the 25 m unsaturated zone before they reach the aquifer. The discusser questioned the use of chlorine and whether sludge should or should not be treated as nitrogen fertilizer.

In his reply, Edworthy stated that the nitrate problem was vitally important and was being investigated. The investigations were also focused on the problem of whether nitrification takes place in the aquifer and to what degree. The authors believe that nitrate concentrations have reached equilibrium and no significant increase is expected.

Besides coliforms, other organisms were investigated and it was found that they behaved in the same way as the coliform group.

A.4 Paper No. 39: "Simultaneous *in situ* Determination of Dissolved Nitrogen and Oxygen by Gas Chromatography," by T. Bilstad (Norway), E. N. Lightfoot, L. B. Polkowski (USA)

Presently, no method for the determination of dissolved nitrogen is mentioned in *Standard Methods*. There is a need for such a method since numerous occurrences of fish kills below dams and reservoirs were observed which were caused by nitrogen oversaturation or a high concentration in the waters.

The paper describes the development of a method based on a modification of gas chromatography. The method and apparatus are described. The membrane diffusion cell inserted into the sampling circuit is the basic component of the modification. For the selected configuration, it was necessary to select a highly permeable membrane.

The method is highly sensitive to temperature; water temperatures must be maintained within 0.1°C. The system produces results with a standard deviation of 0.5 percent and can be used with the same accuracy both for the nitrogen and oxygen concentration measurements.

B.4 Prepared Discussion

Literathy (Hungary) pointed out that research involving new analytical methods should be focused on two problems - the method itself and sample preservation. The problems with sample preservation are not explained in sufficient detail. A water sample which is supersaturated with N_2 cannot be preserved in conventional BOD flasks. Temperature differences may cause problems as well. It is very difficult to maintain temperatures within ±0.1°C under field conditions.

C.4 Floor Discussion

Pomeroy (USA) emphasized the importance of a method enabling measurements of N_2 concentrations. A question was also asked regarding the remaining nitrogen concentration if nitrogen is dissolved under pressure and the pressure was then returned to the atmospheric pressure.

Garletti (Italy) pointed out that they use the multi-disc distractor in the laboratory and also measured gases other than those mentioned in the paper.

Author's Reply - Pure oxygen was used to strip nitrogen. The concentration ranges which were used for calibration and experimental work were 40 to 100 percent of saturation. The state-of-the-art of the method does not allow field application of the method. Field procedures must be developed in the future which would enable carefully controlled temperature conditions. The silastic membranes used in the experiments are much more sensitive than teflon membranes commonly used. The membrane life may be a problem.

The oversaturation of nitrogen may persist for long distances. Oversaturations of 145 to 150 percent N_2 were observed in the Columbia River for distances of 50 km. The method can be applied when water is post-aerated. If N_2 supersaturation is over 150 percent, fish kills may occur and the aeration effect is questionable.

D. Other Observations and Comments

Additional information regarding Paper No. 30 can be obtained from the Greater London Port Authority, Thames Water Authority, and Water Research Centre, Stevenage Laboratory, United Kingdom.

Paper No. 33 is based on Sauty's thesis presented to the Polytechnic Institute in Grenoble, France. Additional information can be obtained from the Department of Hydrogeologie, Bureau of the Geologic Research and Mining, Orleans, France. The information on the warm water injection problem will be published by the latter office.

Paper No. 36 reports on extensive research and surveys of groundwater quality conducted by the Water Research Centre. The field data were obtained in collaboration with the Thames Water Authority.

The last paper of the session (Paper No. 39) reports on work done by the primary author while a graduate student in the Department of Civil Engineering, University of Wisconsin, Madison, from where additional information on the method and future progress can be obtained.

IV. CRITIQUE OF SESSION

The first paper (Paper No. 30) did not represent a new technology nor a new model but rather an evaluation by practitioners of applicability of an older and simple model. The paper itself, its introduction and following discussions, gave a good insight of the model and its use. All questions and replies were related mostly to the use of a model for water quality management. It should be noted that the authors and their institutions have more than 20 years of practical experience with the use of the model for water pollution control of the Thames River estuary which was recently documented as being very successful. The water quality in the estuary, deteriorating for almost a century, was dramatically improved in the last two decades which coincides with the practical use of the model.

The second paper was highly theoretical in nature. However, the paper does present an original application (original to the groundwater problems) of mixing and dispersion theory with some practicability as to its use for studying groundwater pollution transport.

Paper No. 36 reported on problems associated with aquifer recharge by sewage and industrial effluents and land application of sludge. All speakers expressed their concern with such practices, although it seemed that English practices allows such disposal techniques while some other countries (Israel) had serious difficulties and breakdowns with similar systems and geological formations.

The last paper of the session (Paper No. 39) reflected a highly specialized narrow scientific area of analytical techniques. Also, the problem and the need for measuring dissolved nitrogen gas is not as acute or urgent as some other substances.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Although the model of the Thames River estuary is simple and does not represent anything new if compared to the available U.S. models (QUAL II, MIT, San Francisco Bay model), a few items of interest should be mentioned:

1. The model uses a "moving box" concept which evidently reduces the numerical problems often found with "static" Lagrangian coordinate models typical for the U.S.

2. The model realizes the change and variability of the deoxygenation rate based on the degree of treatment.

3. The model, which is relatively simple, has been in a practical use for almost 20 years and the results with its use document the success of the pollution abatement activities. It also shows that water pollution control is not related nor proportional to the complexity of the model.

The second paper represents an original application of a mixing concept which has been known for many years. The concept was originally used for chemical reactors and later extended to surface waters. The significant merit is that the work presented in the paper enables a simple graphical evaluation of dispersion characteristics of an aquifer. However, the techniques and method (tracer injection and evaluation of C-curve) are not different from those used in the USA for evaluation of dispersion and mixing in surface waters and treatment reactors. For similar research on pollutant dispersion in aquifers in the U.S., the experience with tracers and their applicability may be useful, e.g., Rhodamine tracers commonly used in the USA have been found not to be suitable for groundwater dispersion experiments.

Paper No. 36 reported on problems associated with disposal of effluents and sludges on land in not too favorable geological formations. The problems reported in the paper, or raised by the discussions, should be evaluated by U.S. engineers before such practices are initiated in this country. The originality of the paper, if any, is in the methods and survey techniques used to evaluate the effect of the effluent discharges. However, the results may be only applied to similar geological formations.

The last paper (Paper No. 39) represented an attempt to modify the gas chromatograph method for measuring dissolved nitrogen in waters. It is evident that several problems associated with the method must still be solved before the method may be applied to field measurements. However, as pointed out by the author, field techniques for measuring dissolved oxygen concentrations started with a similar laboratory research and evolved into a routine field technique. Since there is a need for estimating the dissolved nitrogen concentrations in water, the research should continue.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: A
Time: 2:00 to 2:45 pm

B. Theme: Methane Fermentation

II. REVIEWER

A. Name: B. P. Sagik

B. Position and Affiliation: Dean, College of Science and Mathematics
The University of Texas at San Antonio
San Antonio, TX

REVIEW OF SESSION

A. Formal Paper

A.1 Paper No. 41: "The Effect of Petrochemical Structure on Methane Fermentation Toxicity," by W. L. Chou, R. E. Speece, R. H. Siddiqi, K. McKeon (USA)

The study was motivated by the desire to utilize anaerobic digestion in the treatment of wastewaters from petrochemical plants 1) to conserve energy (present aerobic treatment is energy intensive), and 2) to produce methane for use as a fuel. The anaerobic process would require a lower input of inorganic nutrients, could be used with heavy metal-containing wastes, and would produce less excess sludge than does the present aerobic process.

Fifty-two different petrochemicals were assayed for toxicity to fermentation by unadapted methanogenic cultures. Adaptation was used to reduce toxicity in some cases. Chloro substitutions, aldehydes, unsaturated bonding, and benzene rings all were found to be toxic to unadapted cultures. Hydroxylation and increased carbon chain length decreased such toxicity. Adaptation decreased toxicity to aldehydes and unsaturated structures (aryl and alkyl, both). From these studies a "relative toxicity number" was established for the toxic compounds.

All fermentations were carried out by a culture of methanogenic bacteria enriched by growth on acetate medium. Warburg respirometers were used throughout the study. The authors acknowledge the obvious: such systems do not measure the toxicity to those organisms which degrade compounds to the form in which they are available to methane bacteria.

Speece presented information to emphasize the energy advantages of anaerobic stabilization as compared to aerobic stabilization for sludge treatment.

B. Prepared Discussion

Wienhusen (West Germany) was familiar with the use of anaerobic treatment in slaughter houses and offered other examples as well. He asked:

1) Are pure culture techniques valid for the mixed cultures (and substrates) found in industry? Unless we can apply this information to full-scale use, this study is not useful.

2) At what concentrations are these studies feasible biochemically, and are these levels industrially feasible?

C. Floor Discussions

Dean (Denmark) gave an historical review on bactericidal agents and asked to see data on structures to which bacteria can adapt.

Matsumoto was concerned with the effect of toxic materials on the acid-producing stage of the digestion process.

Author's Reply - Any predictive basis in chemical structure for groupings is based on acclimation and adaptation. (The questions as to whether studies one can cross-adapt for whole families of chemical compounds was not answered clearly, but apparently this may be possible.) The methanogenic cultures were enriched, not pure, and acclimation may have made them more susceptible to toxicity. He used acclimation as a tool for providing mass inocula (these cultures can degrade even formaldehyde at 3000 mg/ℓ). Speece argued for the advantages of methanogenic techniques. He believed they were especially feasible at temperatures over 20°C (but they will go at lower rates). Although he has no explanation for the mechanisms of toxicity, he argued forcefully that we should remember that toxic materials slow markedly the bacterial doubling time (from 5 days to 30 or more days) and thus he showed the need for an anaerobic filter system that retains solids for a very long time. He presented data on acetate-acclimated cultures adapting to acetone in 20 days and to methyl ethyl ketone in 30-40 days. The resistance to toxic material of acclimated systems is as high as 1000X the resistance of the unacclimated. Speece urged upflow (retention) filters with at least 100-200 days solids retention time.

IV. CRITIQUE OF SESSION

This was a well-studied, well-presented piece of work. The need for a partnership of industrial microbiology and chemical engineering has been accepted in the pharmaceutical industry and in food processing. Speece and his co-workers made a good case for the petrochemical industry joining them.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: A
Time: 2:45 to 4:45 pm

B. Workshop - Water Pollution Problems Arising from Development

Convener: W. J. Cosgrove (unable to attend - substitute Convener was John Pettigrew, also of the World Bank)
Speakers: J. B. Mendis (Bangladesh), D. R. Ellis (UK), U. P. Gibson (US), A. Rance (UK), Mr. Rasmussen (World Bank, US)

II. REVIEWER

A. Name: Robert A. Canham

B. Position and Affiliation: Executive Director
Water Pollution Control Federation
2626 Pennsylvania Avenue, N.W.
Washington, D.C.

III. REVIEW OF SESSION

A. Formal Papers

A.1 In citing a number of statistics about circumstances in developing countries in regard to water services, the Convener set the tone of the Workshop. However, he stated that the purpose of the Workshop was to discuss other constraints relative to providing water and wastewater services. In stating that more than 1 billion people in the world do not have central water supplies and that the financial needs for water supply are more than $60 billion, and the needs for wastewater collection and treatment are $200 billion, the Convener focused on the enormity of the problem.

Many may say that these are not the concerns of the developed countries such as the U.S. and that there is little to be learned from experiences in developing countries when they are far behind the U.S. in providing basic services. However, such views may be fallacious when comparisons are made in detail. For example, the fact that the financial needs for basic utilities in developing countries are overwhelming may lead to some useful experiences that can be applied to developed countries. The severity of the financial requirements may lead to the development of innovative methods that could be applied in rural areas of the U.S. Also, in the process of making some progress toward improvement in developing countries, some of the institutional arrangements may be of value in the U.S.

The speaker from Bangladesh (Mendis), in discussing various circumstances in his country, did not describe a well-developed program to overcome the problems, but some of his descriptions should help people from other countries understand how different the techniques must be in a country like Bangladesh to accomplish meaningful results. The facts are dramatic. The speaker stated that 70 percent of the population is without adequate sanitation. Furthermore, Dacca, a city of 2 million people, has only 5-10 percent of the population sewered and there is no wastewater treatment.

With these circumstances it is obvious that the priorities must be vastly different from those in developed countries. In the allocation of limited resources, basic health problems must take precedence just as they did before safe water was generally accepted to be available in the U.S. The health needs must apply to problems not directly related to water as well as those associated with water. To a great extent the analogy may be made to a treadmill and yet it was not too many years ago that similar circumstances were present in the major Western cities.

When the speaker makes a point that there is a program in Bangladesh to prevent well contamination by priming water control, it emphasizes the vast difference between the conditions in that country and in the U.S.

This is not to say that there are not scattered problems in the U.S. because it is documented that every year there are reported cases of health problems from water supplies, and undoubtedly many that are not reported. These comments apply to the more well-known problems of organisms responsible for enteric disease, e.g., typhoid fever. Even though the U.S. is into a period of concern and action about problems caused by toxic materials, suspected carcinogens, viruses, etc., it makes one wonder whether the regulatory authorities at all levels of government, as well as the technical community, are headed along a path that considers exotics but forgets basics.

The frustrations of an informed individual dealing in a world where grossly inadequate resources, and perhaps commitment, were evident in the remarks of the speaker from Bangladesh. He stated that safe water is a human right for all people. The source was not a national document and thus it appeared that his personal commitment was strong but equivalent dedication from all others that comprise the necessary team was lacking.

A.2 The speaker from UK (Ellis) discussed industrial problems primarily in Iran, Iraq, and Nigeria and the problems in these countries obviously are not identical to those in all others.

While the speaker did not so state, his examples of pollution situations from industry, wherein it was indicated that few pollution controls were imposed as industry was developing, has some similarity to the past experience in this country. It would appear that the imposition of severe pollution control on industry in a developing country would not be practical because the obvious thrust of industrializing is the manufacturing of products that can compete in the world market. Actually the same circumstances are true in this country. Despite the continuing efforts toward effective pollution from industry in the U.S., there is a point when economics becomes a driving force.

It is felt that there is little information to be gained in the U.S. from the pollution programs of industry in developing countries unless some unusual techniques are used to solve industrial pollution. This seems unlikely under the circumstances, however.

These remarks are not intended to imply that developing countries are not interested in environmental control. It is quite the reverse. There is a substantial body of support for wanting the best of everything but the economic pressures tend to cause long delays in pollution control expenditures that add to the cost of the product but have no effect on the quality of the product. One of the points made by the speaker was that industry should not be charged with instant improvement.

The next speaker (Rance) discussed one of the most important parts of any environmental improvement program, whether in a developing or developed country, and that is the manpower and training need.

When it is recognized that progress is slow in the same area in developed countries it should be expected that they would be magnified in developing countries. The speaker confirmed this.

It is difficult to convey satisfactorily to policy people the importance of allocating a high priority to manpower needs even in this country. When one considers the special problems of manpower in developing countries, it is clear that the problems are intensified in comparison.

The speaker demonstrated a good understanding of these special needs. His emphasis on the importance of any plan to be sensitive to social and cultural needs and his emphasis on the need for simple technology were significant.

As in the industrial area, it appears that the opportunity to gain much meaningful information from programs in developing countries about manpower planning and training techniques is slight for developed countries but the opportunity to share information in the other direction is great.

The American speaker (Gibson) agreed with the other speakers about the special problems in developing countries in providing water supplies and wastewater collection and treatment. His analysis that there is evidence of slippage in the period of 1970-75 in the total percentage of the population served by utilities is discouraging. Although he did not provide a detailed analysis of why the statistics show a downward trend, he placed heavy emphasis on the need for increased investments in developing countries.

The speaker's rationalization about using optimizing techniques points up a problem that seems to be fairly uniform. The speaker's analysis of optimizing techniques that led to the conclusion that it is not advisable to use such sophisticated procedures in developing countries suggested that this conclusion was reached only after several were tried. Evidently many representatives from developed countries have attempted to work in this way only to find out that techniques must be simple in order to be successful. It would seem that this message should be better known before complicated efforts are wasted.

There is a growing feeling that when utilities are installed in developing countries, both water supply and wastewater facilities should proceed simultaneously. This is a reversal of the philosophy espoused for many years by the developed countries financial and technical assistance institutions and agencies wherein water supply was supported and wastewater facilities were deferred. The speaker recognized this and also placed strong emphasis on needs to improve services in rural areas.

The World Bank speaker (Rasmussen) discussed and justified sophisticated analyses of water supply schemes in developing countries but these were in larger urban areas where complex techniques are more susceptible to success. The speaker confirmed what others have reported about the shift of the World Bank's priorities from those of mostly large cities and large projects to concern for the rural and small community levels. Its analysis that in 12 countries studied there are less than 2 percent of treatment situations where conventional systems are applicable provides a significant basis for a shift of emphasis.

It would seem that the only way the World Bank could offer loan assistance for the most rudimentary systems such as pit privies, treatment of night soil, etc., would be to obtain a firm commitment from a national government to implement a workable program in these areas. If this is successful, it may have great impact on the state of the health of those in developing countries. On the other hand, it seems inconsistent if the vast populations in urban centers are then neglected and it is predicted that the latter circumstances will not occur.

B. Prepared Discussions

Since this was a workshop the discussions were generated from volunteers in the audience.

C. Floor Discussions

A speaker from Israel (Shuval) criticized some of the speakers for discussing sophisticated treatment systems and supported the World

Bank's shift in emphasis toward simple systems. His principal point was to chide professionals as a group for not spending enough time to find simple solutions. However, it is not quite that simple. The education programs preparing individuals for professional careers are not oriented in that direction and it is unlikely that a wide-spread change will occur in the developed countries.

There was some evidence from floor discussion of newer training programs being developed in France, for example, to deal with the simpler needs but these are being sponsored by the United Nations, not academic institutions.

There were other exchanges of opinions representing from one group criticism of engineers for promoting complicated systems to defensive statements by engineers. In general, little additional was contributed by the discussions.

IV. CRITIQUE OF SESSION

As a general theme, there was general agreement among the speakers that the problems in developing countries are not susceptible to the same kinds of approaches toward solutions as is true in developed countries. Money always is the central problem but perhaps more important is the priority development system to spend the total money available. All speakers decried the promotion of sophisticated systems at the expense of simple techniques. The World Bank's announced shift toward simple techniques is one of significance. However, it is easy to talk in generalities and it will be interesting to watch over a period of time to learn whether actual commitment matches the statements.

Periodically in the presentations it appeared that some of the speakers would have preferred to discuss the more complex treatment systems with which it was obvious they are more familiar.

In the beginning, the Convener indicated that it was the intent to discuss other constraints for water and wastewater (other than financial). Unfortunately, this objective was not reached to a measurable degree. For example, some discussions of the political methods and constraints in developing countries would have been beneficial. Also, there was little brought out in the way of discussions of technical developments that will make major impacts on providing more and better utility service to developing countries.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

As a workshop on the subject of water pollution problems arising from development, it is less likely that the discussion would contribute greatly to American research interests in the traditional scope of research activities.

However, the problems of developing countries pose entirely different sets of research needs than are present in developed countries. At first glance it may appear that there is little compatibility, but it is believed that there is potential value to research programs in the U.S.

One of the discussions spoke of research work in the area of composting of sludge and night soil. Even though substantial work has been done in the U.S. on composting, problems remain. With sludge continuing as the perennial major problem, more research along simpler lines of handling would be desirable. The World Bank's shift in emphasis to simpler systems in smaller communities and to rural areas will have some impact on research efforts with the objectives of attaining workable solutions using less complicated methods. This will have an influence on the American research community.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: B
Time: 2:00 to 4:15 pm

B. Theme of Session: Activated Sludge Sorption and Virus Removal and Distribution in Soils and Ponds

II. REVIEWER

A. Name: James A. Mueller

B. Position and Affiliation: Associate Professor
Environmental Engineering & Science
Manhattan College
Bronx, NY

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 42: "Removal of Organic Dyes by Activated Sludge," by M. Dohányos, V. Maděra, M. Sedláček (Czechoslovakia)

The paper brought out the similarities between the sorptive capacities of the relatively cheap activated sludge and relatively expensive manufactured or artificial sorbents such as activated carbon. Results were presented for adsorption of 20 different dyes of various types by activated sludge. Adsorption equilibria were best correlated using the Freundlich isotherm. Effects of various parameters, both in the liquid phase and due to dye structure were evaluated. The reduction in adsorbability with increasing dye sulfo groups was especially noted as well as pH effects.

The ability of "boiled" activated sludge to adsorb greater quantities of dye than either living or chemically treated sludge due to increased surface area highlighted the sorption capabilities of the sludge. In continuous flow studies, dye removal was directly proportional to excess sludge production with the removals proportional to the batch isotherm data for the various dyes. In addition to the results presented in the paper, Madera commented on the capability of excess activated sludge to remove numerous bioresistant compounds and toxics such as heavy metals. He felt use of an artificial adsorbent such as activated carbon would be required for most full scale applications; however, in some instances use as a pretreatment device either on the influent stream or on a concentrated wastewater may be viable.

A.2 Paper No. 44: "Retention of Viruses During Sludge Application to Soils," by G. Bitton, O. Pancorbo, A. Overman, G. Gifford (USA)

The paper presented the results of laboratory studies with preliminary field data on virus retention in packed and undisturbed soil columns. The major portion of the studies was conducted using a red sandy loam containing 28 percent clay. Initial studies using a 0.01 N $CaCl_2$ solution with poliovirus showed insignificant virus breakthrough. A shift to rainwater at significantly lower conductivity caused substantially no additional breakthrough of virus, thought to be due to the high clay content of the soil. Negligible virus breakthrough also occurred using liquid digested sludge either diluted 1:50 with 0.01 N $CaCl_2$ solution or distilled water. Similar results were obtained when 1 inch of sludge was air dried on the soil for 24 hr followed by elution with rainwater. From 31 to 47 percent of the poliovirus mixed with the sludge was "free" (associated with the supernatant). When added to a fine sandy soil containing only 3.2 percent clay and without air drying for 24 hr, 29 percent virus breakthrough to the leachate resulted. They felt this was due not only to lack of air drying but also to the low clay content of the sand indicating a groundwater contamination potential for sandy soils. In field studies, preliminary results showed no virus in groundwater after sludge lagooning and land application to the red sandy loam soils. Further studies on the interaction of the iron oxides in the red soil and the viruses are being conducted.

A.3 Paper No. 46: "Survival of Poliovirus in Model Wastewater Holding Ponds," S. Funderburg, B. Moore, C. Sorber, B. Sagik (USA)

Batch holding ponds were utilized under actual climatic conditions to evaluate factors affecting virus survival in waste stabilization ponds. High virus concentrations (10^4 PFU/mℓ) were used. In the overlying waters, virus survival was longer the cooler the temperature. The type of wastewater also affected virus inactivation, virus surviving for longer periods of time when primary effluent was used in the pond rather than secondary effluent. Data taken on both supernatant and sediment samples showed a rapid initial buildup of virus in the sediment in the first few days. Extended virus survival occurred in the sediments over the winter months in Austin, Texas, while supernatant dieoff continued. Additional data on the supernatant indicated that marked increases in the rate of virus destruction occurred after varying periods of time for ponds of different depths. This was related to increases in pond pH due to algal growth in the pond which occurred at different times for the various depths. The study results had practical implications - wastewater withdrawn from pond bottoms for land disposal presented a potential health hazard due to the high viral concentrations.

B. Prepared Discussion

B.1 Paper No. 42

Bjorndahl (Sweden) commented on the harmful effects of dye discharges from the textile industry on light penetration and possible accumulation in the food chain. In the textile industry, reactive dyes are the least adsorbed by the cotton and rayon fibers (50-80 percent) compared to direct and acid dyes, thus discharged in greater quantities in the effluent. From their results, reactive dyes are poorly adsorbed by activated sludge but they are greatly adsorbed on activated carbon. He questioned the practical application of using activated sludge and the effect of using a spent dyeing bath where possible interference to adsorption by the activated sludge may occur by the detergent present. He also asked if anaerobic or chemical (especially lime) treatment of the waste sludge prior to disposal would have any effect on the dye. He concluded that physical-chemical treatment would be the best process when the waste contains nonbiodegradable toxic materials.

B.2 Paper No. 44

Lund (Denmark) indicated a number of points which caused difficulty in data usage and interpretation. The high virus concentrations ($\sim 10^4$ PFU/mℓ) used in the study are orders of magnitude greater than found in digested sludge (10-100 PFU/mℓ). Data by others showed a significant effect of initial concentration on recovery, 80 percent recovery at 1000 PFU/mℓ while 0 percent at 10 PFU/mℓ. A number of difficulties in translating laboratory experiments to real world conditions were noted. The first is that sludge autoclaving is not required nor desired since it may change the sludge virus retention capabilities. The second is that laboratory column experiments with 2 inch columns cannot provide meaningful breakthrough data due to channelling along walls and through cracks. It is also difficult to obtain undisturbed cores of fine sand. In the estimation of free viruses, the difficulties involved with measuring viruses in centrifuged sludge were noted. Information on the initial virus quantity added is required. She concluded that the study did provide valuable information on retention capabilities of soils and sludges, although it had limited real world application. She congratulated the authors on initiating field studies.

B.3 Paper No. 46

Bouteille (France) commented favorably on the experimental design which provided the type of controlled environment where virus input is accurately determined but used a field site to get actual climatic conditions. He found the effects of temperature, secondary treatment, sediment concentration, and algae most interesting. He questioned the capability of the PFU technique to accurately assess viral concentration due to possible protection by sediment particles since studies in France showed waste with no PFU present to be still infectious to laboratory animals. The final solution may be to count virus particles by electron microscopy. As in the previous study, use of the high concentration was noted as nonrepresentative. Also, could the higher decay rates during algal growth be due to adsorption on the algae or algae-bacteria complexes? He noted that summer temperatures in Texas providing algal destruction from supernatant in 15 days were not representative of European climate where the summer would be equivalent to Texas winter conditions, providing greater survival times.

C. Floor Discussions

C.1 Paper No. 42

Brouzes (France) supported Madera's approach using activated sludge for removal of toxics, both organic and inorganic, and dyestuffs. He presented a slide of a process installation to accomplish this using staged treatment.

Hsudey (Canada) indicated that for Madera's continuous flow tests, Model "D" with a sludge age of 20 days showed better dye removals than "B" with a sludge age of 7 days. Since the dyes are considered adsorbed and not biodegraded, he expected at longer sludge ages and sufficient dye loadings, the MLSS would become saturated and the unit efficiency for dye adsorption would decrease. This should compensate for the higher solids loading in the high sludge age plant. To explain Madera's results, possibly the sludge may be modifying the dyes to reduce their desorption making the process irreversible. In this context, he requested the nominal dye loadings, g dye/g MLSS.

Fleckseder (Austria) questioned the analytical technique in that the dye concentrations were studied spectrophotometrically at the wavelengths giving the highest absorbence. This optimum wavelength may not be appropriate for the dye after contact with the activated sludge if the dye molecule is split and not adsorbed requiring a different wavelength for analysis. The data obtained may be due to dye splitting and not adsorption.

Martin (Australia) commented that wastewaters consisting of pure dye solutions do not exist in the real world. Could Madera comment on adsorption of dyes in actual wastewater when competition with other molecules exists?

Author's Reply - Bjorndahl didn't compare dye removal by activated carbon and sludge. Madera will do this in future experiments. He expects that all adsorbents will be similarly affected. Due to limited quantities of excess sludge the same total removal of contaminant may not be attained as with unlimited quantities of activated carbon (only cost limited). With respect to the lower adsorbence of reactive dyes, with the same type of dye Madera's results showed widely varying adsorbability for the individual dyes. The process is not practically used yet. With respect to chemical interference, use of Na_2SO_4 salt did not affect adsorption capacity. With respect to sludge disposal problems, Madera has no experience with lime treatment; however, some experiments on alkalizing low pH sludge resulted in no color appearance. In both living and dead cells, photographs showed the dye to be inside the cell, not on the periphery, which is possibly the reason for no desorption. In anaerobic digestion of the sludge, the dyestuffs within the cells are destroyed since in aeration of the digester supernatant and in chemical oxidation of the digested sludge the color does not reappear.

He was pleased by Brouzes' comments and the possibility of pretreatment of influent in one or more stages. In experiments with heavy metals, multistage adsorption provided significantly greater removals than single stage. He recommended use in pretreatment of concentrated wastewater, adsorption of the mixed waste stream on primary sludge and finally adsorption on the mixed liquor, possibly two stage.

Hsudey's comments on loading effects for the low loaded system "D" were explained by Madera as due to a different floc structure of the extended aeration sludge - roughly similar to the boiled sludge, the increased sludge surface providing greater adsorption capacity. Fleckseder's comments on wavelength of analysis are correct and will be evaluated in the future. In answering Mr. Martin, an industrially produced dyestuff was used with activated sludge under controlled laboratory conditions. While real world data were not available, his study indicated the possibility of using a free adsorbent material produced as excess sludge in biological processes.

C.2 Paper No. 44

Sagik (USA) prefaced his two questions by a statement on the field work conducted at San Antonio. There has been little to no field evidence of movement of viruses that have been biologically incorporated in sludge. However, field data indicated that free viruses do move and adsorbed viruses may move as a function of soil properties and climatic conditions. His first question asked about the fate of viruses incorporated in sludge since the major portion of sludge viruses are biologically incorporated. His second question related to $CaCl_2$ used in the experiments. He felt that this may have contributed irreversible virus removal. What were the cation exchange capacities of the soils tested?

Grabow (South Africa) requested information on the fate of bacteria and bacteriophage in the soil since they may penetrate at faster rates than the virus.

Authors Reply - In response to Lund's comments, scale-up of laboratory column data to field conditions is a classical problem. With respect to the virus concentration, high values were required to allow measurements to be practically obtained in their simulated experiments. The authors did not attempt to recover the virus from the soil and were critical of Larkins' method which did not work for them. They are using two methods to evaluate this; one using glycine-EDTA at high pH with reconcentration, and the other, which they are developing themselves, using caesin or skimmed milk to elute viruses and reconcentrate by flocculation at pH of 9.0 to 10.0. In the lab column setups, bulk density effects are now being evaluated on results. In their experiments, started before Lund's work was published, they used the basic system known to soil scientists - 0.01 N $CaCl_2$ solution. In attempting to move their experiments towards more realistic conditions, they are now using a 7 inch column with undisturbed soil and monitoring temperature hourly. In Florida the viruses disappear within 5 days while in Denmark they exist for months due to lower temperatures. In Florida, if the sluge is allowed to dry instead of draining, movement of sludge through the soil will be limited. With respect to the virus strain, poliovirus is widely used and allows comparison with other work. He agreed with Sagik that biological encapsulation will play a predominant role in virus survival and transport. However, when the sludge decomposes, any remaining viable viruses will be transported according to their study results. No data were available on soil cation exchange capacity. In responding to Grabow's question, he indicated that no differences existed between bacteriophage and virus movement in soils. For bacteria, both straining and adsorption are important mechanisms for removal by soil while for virus only adsorption is important due to much smaller size.

C.3 Paper No. 46

Bitton (USA) commented on the importance of virus in sediment of natural water systems where recent studies at Miami have recovered virus in sediment off bathing beaches. He complimented the authors on successfully demonstrating the flocculation sedimentation nature of virus removal from supernatant. He asked if it was possible for the viruses to be resuspended due to benthic activity and also if the greater number of particles in primary effluent protect viruses from solar radiation causing longer survival times. He indicated that the effect of algae, causing either high pH or DO, on viruses is similar to the toxic effect of high pH on bacteria in bacterial-algal systems. In recent studies to be published by Bitton it was found that algae also act as a shield and protect viruses from solar radiation. In answer to Bouteille's question, he indicated that they found no virus adsorption on algal cells. He further asked what the solution was to increased viruses in sediment.

Lund (Denmark) indicated that Sagik's data tended to support the widely held concept that the better the suspended solids removal, the better the virus removal. She also indicated that temperature was the most important parameter for virus destruction, e.g., Danish winters at 0°C required 5 months for good virus removals. She asked for the pond temperature data for the various conditions used by Sagik. The requirement for efficient solids removal from ponds to obtain good virus removal would suggest that more than 2 ponds in series be used. Could better winter sedimentation compensate for the poorer removals at the lower temperatures? She also asked if the algal effect was definitely pH related or were other phenomena involved. Her last comment indicated that discharging sludges with high virus content to receiving waters posed a potential health hazard just as does land discharge.

Grabow (South Africa) asked why only poliovirus was used and not compared to survival of other organisms. South Africa uses stabilization ponds significantly due to land availability and high temperatures and sunlight. They have found excellent virus removal but use bacterial strains to get a better indication of efficiency since they are detectable by simple and cheap methods. His further discussion related to the important role sunlight played in viral inactivation, a parameter not mentioned by Sagik. Greater sunlight penetration may have caused more rapid destruction in secondary effluents compared to primary and may also have provided more rapid algal growth in the shallower ponds. The increased virus survival in sediments compared to overlying waters may also be due to lack of sunlight penetration to the sediments. Temperature change in the ponds is also related to sunlight intensity.

Brouzes (France) indicated that the high chlorophyll levels measured by Sagik were about 10 times greater than in sewage ponds where maximum levels of 300 µg/ℓ were obtained. He commented on the slow algal growth rate in the studies and the possibility of it being due to the surface area-volume relationship. He also indicated that the microecosystem may be more important than suspended solids and wished to know if the microflora on the pond walls had any effect. To compare to other results he would require the general water quality parameters in Sagik's ponds.

Author's Reply - The high concentrations of virus were used to swamp the existing virus and allow a determination of viral distributions. In field studies, they use indigenous virus concentrations, the above studies indicating the need for routine sampling of sediments for virus. With low virus concentrations similar results are found but this requires a complicating viral concentration step. They have determined that there is no attachment of viruses on pure algal cultures. However, in a mixed zoogleal-algal mass, attachment, adsorption and some destruction of viruses occurs. To properly evaluate climatic effects they conducted additional studies in Butte, Montana, and Boulder, Colorado. Similar patterns resulted but over a greater time frame. In response to Bitton, work presently being conducted at Syracuse will determine if virus can pass through the digestive tract of invertebrates unharmed. He feels that the shielding effect of primary effluent is responsible for slower algal growth. He is not convinced that ultraviolet irradiation is significant in his ponds. He feels that sunlight is only responsible for the thermal effects. The actual temperature in the ponds ranged from 9-12°C in the winter to 18-20°C in the summer which was critical in terms of the speed of algal bloom development. With respect to dissolved oxygen, there are no effects, pH being the factor directly responsible for viral inactivation. Laboratory data using pH adjustment alone with no algae, confirmed the direct effect of pH. The solution to viruses in sediment is to use multiple cell ponds since the major sedimentation, which will also occur under ice cover, will be at the pond entrance.

Sagik concluded his reply with the statement that only poliovirus was used since these were models leading to field work. Not all components of the field system could be simulated. Since there are numerous literature data on bacterial survival in holding ponds, these data were not obtained.

D. Other Observations and Comments

In conversation with Madera following the formal presentation, he presented additional data on metals (Cu, Zn, Ni, Pb) adsorption to activated sludge showing the capability of the sludge to continually adsorb metals when placed into solutions with sequentially higher concentration.

IV. CRITIQUE OF SESSION

The activated sludge size effect on adsorption was clearly demonstrated by Madera. The viral removal mechanism by settling and appearance in the sediment was considered to exist in the field, with the data presented by Sagik being one of the first sets to clearly demonstrate this effect. Also, the increased viral removal by increased pH due to algal growth was well documented. The data presented by Bitton, on the marked virus breakthrough in sandy soil compared to clay soil, was interesting. However, the comparison of the two was inconclusive due to the different sludge preparation techniques where that applied to the sandy soil was not air dried prior to elution tending to maximize breakthrough.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Use of adsorptive capabilities of activated sludge for pretreatment of toxic or nonbiodegradable industrial wastes may have slight application in the United States. The requirements for additional sludge handling industrial locations near waste treatment facilities, and final sludge disposal requirements are problems which must be practically and economically evaluated. The research conducted on virus movement and survival both in soil and ponds is highly significant to American research activities as water reuse and health-related aspects receive greater attention.

I. SESSION

A. Day: Wednesday, June 14, 1978
Hall: C
Time: 2:00 to 4:15 pm

B. Theme of Session: Measurement and Forecasting of Nutrients in Stormwater Runoff

II. REVIEWER

A. Name: Kenneth D. Kerri

B. Position and Affiliation: Professor of Civil Engineering
California State University
Sacramento, CA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 43: "The Significance of Plant Nutrient Yields in Runoff from a Mixed Land Use Watershed," by T. J. Grizzard, C. W. Randall, R. C. Hoehn, K. G. Saunders (USA)

One of the purposes of this research project was to identify sources of nutrients (nitrogen and phosphorus) causing cultural eutrophication in the Occuquan Reservoir. The Reservoir is located at the mouth of a major tributary to the Potomac Estuary on the southern periphery of the Washington, D.C., metropolitan area. Seven monitoring stations were constructed on perennial streams in the Occoquan Basin. The sampling program was conducted from 1975 through 1977. The areas monitored included land devoted to silviculture, agriculture, and suburban-urban development. This paper should be read along with Paper No. 31, "The Impact of Atmospheric Contaminants on Storm Water Quality in an Urban Area."

Point source discharges were found to account for less than 15 percent of the total nutrient load during the period of minimum storm runoff. Drainage from urban land was found to export much more nitrogen and phosphorus than an equivalent amount of rural land. Log-linear relationships were observed to exist for Bull Run and Occuquan Creek between both nitrogen and phosphorus loadings (kg/ha) and runoff quantity (cm over the basin area).

Procedures used in this study can serve as an excellent starting point for persons wishing to study and forecast the contribution of various land uses on nutrient loadings. Similar results could be expected in other areas, but one should not expect other basins to produce the same results.

Small urban developments can significantly increase nutrient contributions to nearby streams.

A.2 Paper No. 45: "Determining Nutrient Loading from Rainfall and Runoff in Small Rivers," by H. R. Verworn (Federal Republic of Germany)

The author indicates that the problems of eutrophication require the consideration and treatment of nutrients even in small rivers, especially when they are contributors to lakes and rivers. The aim of this study was to develop methods for analyzing and describing the nutrient loading in relation to the parameters affecting it rather than investigate and comment on the actual nutrient levels in the catchment areas studied.

A 20 km^2 catchment area near Hanover, Germany, was studied which consisted of 44 percent forest, 36 percent farm land, and 20 percent urban. Storm runoff resulted mainly from urban areas while the rest of the catchment area produced significant runoff only after excessive rainfall. Samples were collected at 30 or 60 min intervals during periods of runoff. Stream flows and nutrient concentrations were separated into base flows (or concentrations) and direct runoff (or concentrations). The principles of the unit hydrograph were applied to develop characteristic pollution graphs (CPG) for nitrate-nitrogen and total phosphorus. Coaxial relationships using amount of rainfall, month of year, elapsed time since last storm and duration of storm are developed to forecast concentrations of nitrate-nitrogen and total phosphorus.

The procedures used in this paper to analyze data and to develop coaxial relationships and CPG are very ingenious. Other researchers attempting to forecast nutrient loadings on receiving waters should be familiar with these techniques and consider using them. Results from this study cannot be applied to other basins without considering the differences between the basins; however, the results are indicative of what one might expect in similar basins.

A.3 Paper No. 47: "Nutrient Budget for a Residential Stormwater Catchment in Durban, South Africa," by D. E. Simpson, J. Hemens (South Africa)

In the Republic of South Africa, water supplies are generally dependent on shallow impoundments with high solar energy input which undergo seasonal stratification. Several of these impoundments already exhibit moderate to severe symptoms of eutrophication which cause complex management problems. This study is an initial attempt to obtain quantitative data on the amounts of nitrogen and phosphorus that may be discharged in urban stormwater drainage in South Africa and to differentiate between the amounts of nutrients derived from atmospheric sources and those from urban activities.

The catchment area studied covers an area of 6.8 ha and lies at the head of a small valley opening eastward from a ridge lying approximately parallel with the Indian Ocean coastline at Durban. The impermeable surface area is 20 percent of the total area. Road surfaces account for 75 percent of the impermeable area and the remainder is comprised of parking areas and roofs draining to the stormwater system. Approximately 35 percent of the catchment area is tree covered and the remainder consists of grass, gardens, vacant lots and parks.

A collection apparatus for atmospheric fallout and rain collection was situated on the roof of a four-story laboratory building located 950 m outside the catchment boundary. This site was selected for security reasons and to avoid contamination from vehicle exhausts and windblown dust and detritus. Sample bottles were changed as soon as possible after each rainfall event. The stormwater drainage system was sampled from an open discharge pipe in a small public park.

The results indicated that there was a net export of all forms of phosphorus, but a loss or retention of all soluble forms of nitrogen in the catchment. Sources of phosphorus other than the atmosphere are considered to be vehicle exhaust emission and materials derived from vegetable matter such as leaves. Concentrations of all forms of nutrients are highest at the beginning of runoff and decrease during the event. Soluble phosphorus concentrations do not show this pattern to the same degree. Atmospheric deposition rates on the catchment do not show marked seasonal differences but runoff export is seasonal and is related to the rainfall pattern. The contribution of nutrients from impermeable surface runoff is an important factor to be considered if urban development occurs in the catchment of an impoundment or if limitation of nutrients discharged in effluents is contemplated.

B. Prepared Discussion

B.1 Paper No. 43

Toerien (South Africa) noted that this paper could be most appreciated if considered in conjunction with Paper No. 31, "The Impact of Atmospheric Contaminants on Storm Water Quality in an Urban Area," by the same authors. Other researchers, conducting similar studies, must be aware of the need for well equipped sampling stations and laboratory facilities if they expect to achieve similar successful results.

Toerien requested the authors to respond to three significant questions:

1. What was the composition of the urban development?
2. Was the wastewater collection system a combined or separate system?

3. Why was the nutrient contribution so high?

Toerien revealed that the City of Johannesburg uses a 2 km long ditch below the discharge to eliminate or reduce nutrients from a treatment plant effluent. He emphasized the need for effective land management practices to control nutrients from nonpoint sources.

B.2 Paper No. 45

Isgard (Sweden) warned readers of this paper that they must be aware of the individuality of all catchment areas, especially this one when compared with other papers presented at the Conference on this topic. All findings must be related to general conclusions.

The coaxial method used is a very promising approach to physical phenomena that are nonlinear and are not normally distributed. Also, the application of unit hydrograph theory to the development of pollutiongraphs is a significant contribution. Water temperature should have been included in the study. The elapsed time between storms is a very important parameter and has been stressed by other authors at this Conference.

Isgard raised the following questions:

1. Why does the concentration of nitrogen decrease with time between storms?
2. Why were the statistical variations for water quality parameters so high?

Researchers conducting this type of study must develop a carefully designed experiment and follow systematic research procedures. This paper will serve as a good guide for future researchers in this area.

B.3 Paper No. 47

Stahre (Sweden) believed this paper was a valuable contribution to the field. The results provide very helpful information to researchers wishing to model storm water characteristics. Findings presented in this paper are similar to results reported by others at this Conference.

Stahre expressed concern regarding the following matters:

1. The atmospheric collection device is 1 km from the catchment area. What is the impact of this 1 km distance?
2. What is the impact of the time interval between storm events?
3. What are the specific sources of atmospheric pollutants and the quantities of these emissions?

C. Floor Discussions

C.1 Paper No. 43

Characklis (USA) reported that he had observed essentially the same results in a watershed area in Houston, Texas. He asked the authors to respond to two questions:

1. Is there a need to control nonpoint sources?
2. Is the water quality in impoundments deteriorated by nutrients from nonpoint sources?

Grovzet (France) indicated that he had found comparable results in a much larger catchment area (100 km^2). He asked the authors if they experienced problems with sampling equipment failures and how they coped with freezing conditions.

Author's Reply - Grizzard answered Toerien's questions as follows:

1. The Bull Run catchment area is 10 to 15 percent developed. There is essentially no industry in the watershed, but there are concentrations of commercial developments with large shopping malls and parking lots.
2. The wastewater collection system consists of separate storm water and sanitary collection facilities.
3. Major sources of plant nutrients include: a) applications of fertilizers by homeowners; b) auto emissions; and 3) atmospheric dustfall and washout.

He indicated that he felt that there was no effective cooperation between agencies regarding land use planning.

Grizzard responded to Characklis' comments by indicating that he believed there is a need to control nonpoint sources since from 50 to 70 tons/yr of copper sulfate must be used to control algae. Both structural and nonstructural approaches are needed to control problems caused by pollution from nonpoint sources. Today there is no information for design engineers to forecast the effectiveness of management practices to control pollution from nonpoint sources.

Grizzard answered Grovzet by indicating that they also experienced problems keeping equipment functioning properly.

In conclusion, Grizzard indicated that a large portion of the total nutrient load occurs during a few storm events. A potential solution to the eutrophication of small water supply reservoirs would be to develop the ability to bypass these heavy loads.

C.2 Paper No. 45

Benedak (Hungary) reported that he had conducted a similar study in Hungary to protect a beautiful lake for summer swimming. They have a routine monitoring program and material balances of nitrogen and phosphorus for both point and nonpoint sources. A detailed study of a small, specific subcatchment area revealed significant amounts of nutrients in storm waters. Hungary has developed retaining ponds and weed plantations at the mouths of small catchment areas. Approximately 20 percent of the phosphorus and 40 percent of the nitrogen contributions are from precipitation. Benedak asked the author how to curb pollution from precipitation and then answered the question by saying the stacks should be closed.

Zobrist (Switzerland) wondered how the author determined that nitrate is not dependent on rainfall duration, but that total phosphorus is dependent. He also asked if similar results could be obtained using multiple regression analysis.

Author's Reply - Verworn responded to Isgard's comments that this catchment area was selected in order to study both base flows and runoff conditions. Temperature is considered in the coaxial relationship by the month parameter. There is no explanation for the nitrogen decrease with time between storms. More data points would be helpful and might result in adjustments to the coaxial plots, but the procedure is appropriate. A greater number of samples would be helpful in the area of the rising limb of the hydrograph.

Verworn answered Benedak's comments by stressing the need to measure the nutrient contribution from precipitation. He did not know of any way to improve the water quality of precipitation except to control stack emissions.

C.3 Paper No. 47

Author's Reply - (to Stahre's questions) -

1. The atmospheric fallout collector was located 1 km from the catchment area for security reasons at a site safe from vandals. Nutrient fallout does not vary much over the area and other stations greater distances from the catchment area report similar results of nutrient fallout. The air mass is similar or the same throughout the entire area.

2. The interval between storm events was not considered during this project due to lack of equipment, but will be considered in future studies.

3. The sources of nutrient fallout were probably from small particulate matter resulting from wind erosion. Nitrogen and phosphorus levels appeared to increase during periods of

periodic grass burning. Winds do not blow industrial emissions towards the catchment area and there is no domestic heating due to climatic conditions.

D. Other Observations and Comments

Many nations are concerned regarding the impact of pollutants from nonpoint sources. Most researchers acknowledge that an impact exists, but they do not know the extent and magnitude of this impact in comparison with the impact from point sources. Another problem is that they are unable to accurately forecast the impact on receiving waters or success of potential solutions such as land management practices or actual treatment processes.

Apparently the Swedish Environmental Protection Board is divided between whether future wastewater collection systems should be combined or separate sewer systems. Everyone agrees that stormwater runoff and sewer overflow contribute a significant impact on receiving water degradation. No one has the funds to construct and operate stormwater treatment facilities. The major concern regarding storm water runoff is the impact of phosphorus on the eutrophication of small lakes and streams.

Norway has serious problems regarding the eutrophication of lakes and fjords. Last month the Oslo Fjord set a world record for algae concentrations. This problem will be partially solved by the construction of a large intercepting sewer that will convey wastewater around the Oslo portion of the fjord to a new treatment plant being built under a mountain. Several storm water overflows exist along this intercepting sewer and solutions are being sought to treat sewer overflows during storms.

Approximately the equivalent of one billion U.S. dollars is planned to be spent to save Lake Mjosa in Norway. These funds will be used to collect and treat domestic wastewater as well as to implement practices to control nonpoint sources.

South Africans are concerned regarding the impact of storm water on the eutrophication of surface waters. At this time the Water Research Commission is not sponsoring any projects on storm water problems. However, a research program in this area will probably be instituted in approximately two years. The type or direction of the research is not known.

In Belgium they are not especially concerned with storm water runoff at this time. They have combined storm water and wastewater collection systems and it rains continuously. Belgium has very few wastewater treatment plants and most collection systems discharge directly to receiving waters. They are starting to build separate storm water and municipal wastewater collection systems and also to build wastewater treatment plants. They have little interest in storm water runoff or other nonpoint sources at this time because they must concentrate their resources and efforts on treating municipal wastewaters.

Apparently England is not overly concerned regarding the impact of storm water runoff on wastewater treatment plants because most precipitation is light and continuous, rather than the intense precipitation encountered during short periods in the U.S. However, there is concern regarding the impact of nonpoint sources on receiving water quality and beneficial uses.

IV. CRITIQUE OF SESSION

All of the papers described storm water sampling and collecting programs. The major contributions of all three papers were the techniques for analyzing data and presenting the results in a format that could be used to forecast impacts. These papers will be most helpful to persons preparing environmental impact statements (EIS) who must forecast changes in nutrient loadings as a result of various land use activities.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The authors and discussers stressed the need to consider each catchment area on an individual basis. When American researchers are confronted with the tasks of 1) identifying the extent and magnitude of water pollution from storm water overflows and other nonpoint sources, 2) proposing solutions to water pollution problems caused by storm water runoff, and 3) evaluating the impact of proposed solutions, these papers will prove to be most helpful references.

A floor discusser from Hungary (Benedak) and a prepared discussion by Toerien (South Africa) revealed potential solutions to eutrophication caused by storm water runoff. In Hungary retaining ponds and weed plantations have been used to remove nutrients from storm runoff waters. The City of Johannesburg uses a 2 km long ditch to remove nutrients from the effluent of a wastewater treatment plant. Both of these techniques require little energy. Research should be conducted to determine land requirements, design loading criteria and actual nutrient removal efficiencies.

All of the papers reveal that cost effective treatment processes and land management practices must be developed to help solve water pollution problems caused by storm water runoff and sewer overflows.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: A
Time: 9:00 am to 12:30 pm

B. Theme of Session: Design of Multipurpose Integrated Physical-Chemical-Biological Wastewater Treatment Plants

II. REVIEWER

A. Name: Michael C. Kavanaugh

B. Position and Affiliation: Supervising Engineer
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III. REVIEW OF SESSIONS

A. Formal Papers

A.1 Paper No. 48: "Chemical Precipitation of Wastewater with Lime and Seawater," by L. Vråle (Norway)

This paper discusses the addition of seawater to lime precipitation of wastewater for phosphorus and organic carbon removal. Norwegian waters are generally soft and the particulate phosphorus compounds formed by calcium precipitation are difficult to remove by sedimentation. Addition of magnesium to these wastewaters, however, produces a settleable floc at pH above 10.0, due to the formation of magnesium hydroxide which serves as a flocculant aid.

Because many cities are located near the coastline in Norway, a process was evaluated using seawater as the source of magnesium. Pilot and full-scale plant tests were conducted in which varying amounts of seawater were compared. With the addition of 2 to 3 percent seawater, the lime dose could be reduced from about 400 mg/ℓ to 250 mg/ℓ calcium hydroxide, while maintaining 95 percent removal of total phosphorus and 70 to 80 percent removal of organic material. No significant increase in sludge volumes for the new process was noted.

A.2 Paper No. 51: "Experiences in Process Development in Biological-Chemical Treatment of Municipal Wastewater in Sweden," by S. Grönqvist, H. Holmström, B. Hultman, L. G. Reinius (Sweden)

This paper summarizes an evaluation of operational data from selected physical-chemical-biological treatment plants in Sweden. Up to

1977, over 600 such plants were in operation in Sweden treating wastes from about 66 percent of the population. Of these plants, only 10 were surveyed in the present paper. Each of these plants, however, had a different process configuration for phoshporus removal. The principal process combinations included pre-precipitation, simultaneous precipitation, and post-precipitation, using all of the three common chemical precipitants. In addition, solids-liquid separation was achieved by a variety of techniques including flotation, microstraining, deep bed filtration, and sedimentation.

The paper attempts to compare the performances of these systems based on average effluent phosphorus concentrations. The authors conclude that effluent concentrations of total phosphorus below about 1.2 mg P/ℓ are easily achievable by all systems. Effluent concentrations below 0.5 mg P/ℓ will likely require the use of a deep bed filtration system. It was found that phosphorus was released from sludges obtained from simultaneous precipitation plants when held under anaerobic conditions if the Fe/P molar ratio was less than 2. Satisfactory effluent quality with respect to phosphorus can be achieved through proper control of the Fe/P mole ratio, pH, and proper design of the solids-liquid separation process. No differences were observed between flotation and sedimentation when used for solids-liquid separation in post-precipitation processes.

Lime was not effective in post-precipitation at pH values between 11.0 and 12.0 due apparently to poor solids-liquid separation. The recirculation of inorganic sludges from the post-precipitation process to the aeration basin resulted in slightly improved effluent phosphorus concentrations and permitted a 30 to 50 percent reduction in iron doses. The data presented in the paper should provide useful information to designers for selection of the appropriate process combination required to achieve a given effluent quality with respect to phosphorus. The lowest total phosphorus residuals were achieved through the use of simultaneous precipitation followed by contact or direct filtration with an additional chemical dose prior to the filter. Under these conditions, effluent levels below 0.3 mg P/ℓ were easily obtained.

A.3 Paper No. 54: "Basis for the Design of Alternative Chemical-Biological Wastewater Treatment Processes," by W. Gujer, M. Boller (Switzerland)

This paper describes the results of long-term investigations of combined chemical-biological wastewater treatment for the purpose of developing design data. Tests were conducted in both pilot scale and semitechnical scale (16 m^3/day and 100 m^3/day), respectively, using Zürich wastewater. The chemicals tested included lime, alum, ferric chloride, and ferric sulfate produced by the Lurgi process from ferrous sulfate. The four processes investigated included pre-precipitation with ferric chloride, simultaneous precipitation with ferric chloride, simultaneous precipitation with ferrous sulfate, combined with partial to complete nitrification. A range of mean cell residence times was investigated.

The authors attempted to develop design parameters which would lead to optimum design of a combined chemical-biological system given specific effluent discharge requirements. These design parameters include hydraulic loading in the primary clarifier, constant versus step control of chemical dosing, the effect of the chemical addition on *nitrification, relative phosphorus removal in the various processes*, effects of chemical precipitation on reactor volume for equivalent nitrification, residual dissolved organic carbon (DOC) from the various processes, sludge yield coefficients, total solids production, sludge dewatering characteristics, settling properties of the activated sludges, and an evaluation of the nutrient fluxes of carbon, nitrogen and phosphorus in the processes investigated.

The paper emphasizes the importance of conducting integrated experiments in which all aspects of the physical-chemical and biological process combination are investigated. The design variables are interrelated and, consequently, useful design information can only be developed using such integrated-type experiments.

A.4 Paper No. 57: "Physical Chemical Treatment of Anaerobic Filter Effluent," by F. B. DeWalle, E. S. Chian (USA)

This paper presents the results of a variety of investigations for removing dissolved organic carbon from a high strength waste stream following treatment with an anaerobic filter. The waste stream was a leachate from a solid waste disposal area with a COD of approximately 32,000 mg/ℓ. The effluent of the anaerobic filter was treated by activated carbon, ion exchange, ozone, ultrafiltration, reverse osmosis, and chemical precipitation. Sand filters without coagulation were compared to ultrafiltration for pretreatment prior to reverse osmosis. Studies were conducted generally in batch tests. Attempts were made to characterize the types of organics which were removed by the individual processes investigated. Isotherms with virgin activated carbon were prepared and column studies were conducted with the effluents of the various treatment processes. In addition, the effects of aeration on the anaerobic filter effluent were studied.

The authors state that the greatest organic removals were achieved with a combination anaerobic filter followed by ultrafiltration and reverse osmosis. The next best combination was an anaerobic filter followed by an aerated lagoon, sand filter, and activated carbon. Ion exchange, ozone and chemical precipitation with lime were not effective in removing organic materials in this case. No economic evaluation of the process combinations was provided. The authors also concluded that sand filtration prior to the reverse osmosis unit was less effective than ultrafiltration.

B. Prepared Discussion

B.1 Paper No. 48

Possi (France) was concerned with the application of the reported results to wastewaters in other countries, in particular France, where wastewaters are usually harder. It was felt that the cost of the suggested process might be a problem, hindering its application. In particular, operational problems associated with seawater intakes, intrusion of biological materials into the plant, clogging and corrosion of the intake lines, and the capital costs of reservoirs and pumping stations were mentioned. The author of the paper stated, however, that no reservoir was required and that the use of magnesium chloride or other magnesium salt was too expensive in Norway. Thus, seawater was explored as an alternative source. The pumping costs and capital costs could be quickly recovered by savings in the lime doses. Also, to date the plant has had no corrosion problems and biological growths have been contained by locating the seawater intake at a depth of 15 m.

B.2 Paper No. 51

Nesbitt (USA) suggested that the paper would be valuable to design engineers concerned with meeting increasingly stringent effluent discharge standards. Speaking of his experience in Pennsylvania, the discusser stated that effluent requirements were as low as 0.13 mg P/ℓ which, in their case, could only be achieved through the use of simultaneous precipitation followed by filtration and the addition of alum prior to the filter. In some parts of Pennsylvania, treatment plants must achieve effluents with 0.03 mg P/ℓ and the discusser did not know how this low level could be achieved with present technology. The discusser also emphasized the importance of granular media filters following chemical precipitation which produced low total phosphorus levels and asked for more information on the filters used. The use of granular media filters and sludge recirculation in the Swedish plants appeared to provide a more consistent effluent quality.

In reply, the author suggested that if an effluent phosphorus level less than 0.2 mg P/ℓ were required, a process combination of simultaneous precipitation with ferrous sulfate followed by biological treatment with iron bacteria growing on RBC's and granular media filters was encouraged. This process was undergoing preliminary investigation and may produce total phosphorus concentrations as low as 0.01 mg P/ℓ according to the authors.

B.3 Paper No. 54

Rosen (Sweden) criticized the authors for not considering post-precipitation in their study. This process has been widely used in Sweden and the practical value of the paper would have been improved if post-precipitation had been evaluated. The author commented that this process was not cost-effective in Switzerland.

The only post-precipitation system in Switzerland has not been successful and has now been converted to a simultaneous precipitation process. The formal discusser suggested that because of poor settling performance in the primary clarifiers during pre-precipitation experiments, all systems may have been performing as if they were simultaneous precipitation processes. The author responded that although the performance of the primary clarifiers was not optimized, 50 percent or greater removals of suspended solids were achieved in the primary clarifier.

B.4 Paper No. 57

Bernard (France) felt that the processes evaluated by the authors were much too complicated for application in developing countries. In addition, the discusser felt that the authors had not addressed the problem of membrane fouling. He also questioned the use of virgin activated carbon in the batch experiments. The author agreed with Bernard that the processes were quite complicated. He felt, however, that the information could be translated to more simplified technology such as the use of soil anaerobic filters.

C. Floor Discussions

C.1 Paper No. 48

Idelovitch (Israel) emphasized the importance of the appropriate magnesium level in lime treatment of sewage. In Israel, magnesium chloride is added at the Tel Aviv Reclamation Plant. The use of magnesium has resulted in considerably improved performance with respect to the removal of dissolved organics, solids, and heavy metals. The magnesium is transported in solid form and is then added at the sewage treatment plant. Magnesium is responsible for improved particulate removal but, in the discusser's opinion, was not related to the removal of dissolved phosphorus; he questioned this statement on the part of the authors.

The author responded that in laboratory studies with magnesium, they found improved dissolved phosphorus removals. No mechanism was suggested. There was a slight improvement noted with the addition of seawater, perhaps because of the additional calcium and other salts added.

C.2 Paper No. 51

Hahn (West Germany) emphasized that removal of phosphorus alone was not the primary criterion for process selection. He suggested that the overall process performance with respect to both nutrients and organics would be controlling. He also was disappointed that sludge treatment was not discussed and suggested that sludge treatment would have a significant impact on selection of the appropriate process combination. A discusser from the UK asked what the authors would recommend for phosphorus removal using trickling filters. The authors suggested the use of post-precipitation or pre-precipitation. The author agreed that sludge disposal was indeed an important factor. Sludge disposal in Sweden is generally on land. The build up of heavy metals in the soils continues to be of concern.

C.3 Paper No. 54

Several discussers questioned the significance of the inhibition of nitrification by the use of ferric sulfate. The two mean cell residence times (MCRT) mentioned with and without ferric sulfate differed by approximately 20 percent. Sutton (USA) asked whether this was statistically significant. Sutton also mentioned that sludge production seemed low compared to experiments that he conducted in Canada. The authors were also criticized for the failure to optimize flocculation facilities in the pre-precipitation process. A discusser from Austria mentioned that simultaneous precipitation was also a good solution to bulking problems in the activated sludge process which affects 30 to 40 percent of the activated sludge plants in Austria. He also mentioned that Austrians have been using ferric sulfate and have not observed any inhibition of nitrification, although no data were provided. The authors agreed that the flocculation facilities had not been optimized, but stated that the performance of the pre-precipitation clarifier was nonetheless acceptable. They did not want to generalize the inhibitory effect of ferric sulfate because of the many factors involved, and suggested that each system must be studied on a case-by-case basis. Sludge disposal options are also very site-specific and, thus, the authors felt justified in overlooking the ultimate sludge disposal options for each one of the processes investigated.

C.4 Paper No. 57

Van der Meer (Netherlands) suggested that the author was discussing new applications of old methods. He questioned whether the research was, in fact, relevant to pollution problems. The question was raised whether or not the process combination evaluated would ever by applied. In his opinion, the organic loadings of the processes were much too low and were economically unfeasible. Thus, the research was not relevant in his opinion. He mentioned investigations which were conducted in his laboratory evaluating an expanded bed filter also treating high-strength wastewaters. This permitted higher loadings (up to 40 kg COD/m^3/day) with contact times between 2 and 10 hr. This resulted in COD removals up to 95 percent. Details were vague, however.

The batch-test procedures used by the authors were criticized by one discusser who mentioned that membrane clogging will be a serious difficulty with these high-strength wastes. In particular, it was mentioned that biological treatment is probably a superior technique to the use of sophisticated, energy-intensive membrane processes. One discusser questioned the reproducibility of the data. He also felt it was difficult to compare the process combinations because of the batch-test procedures and the use of virgin activated carbon. The author agreed that aerobic biological treatment should follow the use of an anaerobic filter, somewhat in contradiction to the conclusions of the article. He mentioned that the organic materials in the leachate were difficult to degrade and, consequently, the physical-chemical techniques mentioned were investigated. The author stated that contamination of groundwater aquifers is a major problem in the United States and treatment of leachates from sanitary landfills was an alternative that needed to be explored. This was the relevance of the research conducted. He also re-emphasized that ultrafiltration appeared an effective way of removing suspended solids prior to reverse osmosis.

D. Other Observations and Comments

The four papers presented in this session contained a considerable volume of information in a very condensed form. All those interested in this subject are urged to contact the authors for additional information and reports on the research findings. In particular, the authors of the Swedish paper have available considerable information (which was not presented) on sludge characteristics from the various chemical precipitation processes. The papers also demonstrated that the chemistry of the precipitation process is perhaps the most critical element in system design to achieve a desired level of residual total phosphorus in the effluent.

In some areas in Europe, ferrous sulfate is used as the chemical precipitant for the removal of phosphorus. The ferrous sulfate is oxidized to ferric sulfate by a patented Lurgi process. Whether or not this is a cheaper system compared to purchase of the chemicals remains to be seen. The Rotterdam Water Works uses ferrous sulfate and the Lurgi process. According to Rook, however, the chemical costs, anticipated to be less than purchase of the chemicals, were approximately the same.

These particular papers should also be contrasted with the information provided in other sessions, for example, the South African experience with removal of phosphorus by biological treatment. South African researchers have reported a luxury uptake-type phenomenon. This was also reported in the American literature and Union Carbide sells this process commercially. The papers illustrate, however, that there is still much to learn about optimizing the physical-chemical and biological processes available to the design engineer for achieving a desired effluent quality.

IV. CRITIQUE OF SESSION

The paper by Vråle presented an intriguing idea for improving lime precipitation of sewage in coastal regions. Utilizing seawater as a source of magnesium will require an economic evaluation. This was not presented in the paper. The authors claim, however, that the savings in chemicals justified the use of the seawater addition. The authors neglected sludge handling and sludge characteristics and this might have been an important consideration given the difficulties of dewatering sludges when large amounts of magnesium are present.

The Swedish paper presented in a reasonable fashion a broad summary of chemical precipitation plants in Sweden. The information presented was somewhat diffuse however and a statistical comparison of the treatment combinations was not conducted. Thus, the difference in phosphorus removal efficiencies of the various systems investigated could not be connected to specific causes. It is not clear if inadequate chemical dosing or solids-liquid separation was the factor controlling removal of phosphorus. The authors also overemphasized effluent quality with respect to phosphorus as the parameter which would determine the selection of the appropriate chemical precipitation system. This was criticized by some of the discussers and certainly is an oversight on the authors' part. Sludge handling and ultimate sludge disposal problems may override effluent quality control. Details of the individual processes were also not presented; in particular, filter designs were not discussed. The paper also would have been strengthened with the addition of cost data.

The paper presented by Boller and Gujer summarizing Swiss experience on the physical-chemical-biological systems is one of the most thorough papers on this subject presented to date. The practical information is rich with insights into the performance of various combined systems. It appears that most aspects of the design problem have been investigated. The paper was well presented and well received. It was especially gratifying to see the use of mass balances on various components in the systems in order to verify the data collected. There may be some problems with scale-up from the experiments conducted with respect to flocculation in the pre-precipitation step as well as solids-liquid separation in the clarifier. These problems, however, are inherent to pilot or semitechnical-scale investigations.

The paper by DeWalle lacked clarity. The main justification for the research, as well as the objectives of the research, were not clearly presented. The relevancy of the research was questioned during the floor discussions and the utility of the research results presented was not clear. The authors utilized batch studies in general to investigate the combinations of processes. This did not permit proper evaluation of these systems because biological activity on the activated carbon or membrane clogging are significant factors in design of such integrated systems. The author claimed that ultrafiltration was superior to filters as a pretreatment for reverse osmosis but no data were provided for this opinion. Because the filters were used without precoagulation, this was not a surprising result. However, proper design of the granular media filters prior to reverse osmosis would likely demonstrate that filters were more cost-effective than an ultrafiltration system. In general, the authors avoided the question of cost-effectiveness and this is a serious deficiency in their study. In an era of concern over energy conservation it is disturbing to see that processes were selected apparently randomly without consideration for the energy costs incurred.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Because phosphorus removal is not a critical concern in coastal areas where eutrophication problems appear to be nitrogen-limited, the Norwegian experience with seawater does not appear relevant to American practice. The effect of magnesium on improving the flocculation of calcium phosphate, calcium carbonate, and suspended solids is also well known. The information provided by the Swedish authors is potentially of importance for the selection of the appropriate chemical precipitation system given a desired total phosphorus level in the effluent. The results emphasize the importance of granular filters or efficient solids-liquid separation. Achieving a residual total phosphorus less than 0.5 mg P/ℓ will generally require granular media filters or their equivalent.

The solution to nutrient removal problems will require an economic analysis of all options. The final process will be site-specific and thus the results of other investigators are only marginally useful. Nonetheless, the methodology presented and the various combinations investigated will provide the designer in American practice with useful background data.

The results of the Swiss investigation may be a major contribution to improved wastewater treatment design in which multiple constraints are encountered. This research demonstrates the need for integrated pilot or semitechnical-scale experiments in order to evaluate the complex interactions between the physical-chemical and biological phenomena. This important strategy is also of concern in studies of activated carbon for organics removal. Biological activity cannot be avoided except at excessive cost and this phenomenon must be accounted for in design. The paper emphasizes a more rational approach to these problems which would incorporate the most desirable aspects of the physical-chemical-biological phenomena occurring. The specific data presented on sludge characteristics and the impact of chemical precipitation on nitrification may be useful to American practice for facilities treating wastewaters with characteristics similar to those found in Zürich, Switzerland. It is also worth noting that the Swiss approach to organics analyses is to measure total or dissolved organic carbon in lieu of BOD. This procedure has many advantages, including more rapid analyses and the opportunity to conduct carbon mass balances. It is recommended that TOC measurements be conducted in conjunction with other measures of organic carbon in wastewater treatment studies.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: B
Time: 9:00 am to 12:30 pm

B. Theme of Session: Improved Physicochemical and Biological Treatment

II. REVIEWER

A. Name: Richard A. Conway

B. Position and Affiliation: Development Associate
Research & Development Department
Chemicals and Plastics Division
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South Charleston, WV

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 49: "Ozone Initiated Oxidation of Solutes in Wastewater: A Reaction Kinetic Approach," by J. Hoigné, H. Bader (Switzerland)

Ozonation to remove trace contaminants was studied at the Swiss Federal Institute for Water Resources and Pollution Control (EAWAG) using chemical reaction kinetics. Two types of reactions were characterized:

1. Direct oxidation by ozone molecules (O_3)

   Highly selective (few solutes amenable to oxidation)

   Slow (minutes)

   Favored by low pH (lessens O_3 decomposition)

   Favored by free-radical ($R^\cdot$) scavengers

2. Oxidation by decomposed ozone ($OH^\cdot$)

   Unselective (oxidizes all types of organics and inorganics)

   Fast (microseconds)

   Favored by high pH (OH^- catalyzes ozone decomposition)

   Favored by secondary radicals ($R^\cdot$) acting as chain carriers

The rates of the first type of oxidation can be calculated from the concentration of ozone and the second-order reaction rate constants measured for specific solutes in water. In regard to the second type reaction, the amount of decomposed ozone required to eliminate a specified solute to a specific level is proportional to the sum of the rates with which the sum of solutes present consume $OH^{\cdot}$ radicals. This model for ozone oxidation lends considerable insight into a range of previously observed phenomena.

Oxidation by undissociated ozone was studied at low pH in the presence of a free radical scavenger. Reaction rate constants were determined for various solutes. For example, at an ozone concentration of 5 g/m^3 (10^{-4} M), 37 percent of the phenol present was "eliminated" (see later discussion by Kavanaugh for definition of this term) in 10 sec, while toluene took about 1000 sec. Rate constants were determined for 17 solutes.

Oxidation by dissociated ozone was studied at high pH in the absence of those relatively few compounds amenable to oxidation by ozone molecules. In relative terms, butanol required about 20 g O_3/m^3 for 37 percent elimination, while acetic acid required about 500 g/m^3. Rate constants for reactions with 14 solutes were determined.

In addition to pure compound studies, reactions with a biologically treated effluent were characterized. Ozone half-life first was determined in various waters and wastewaters at various pH levels. The lifetime of ozone increased about four-fold per unit of pH reduction. Using these values and the previously determined reaction rate constants, extents of organic reduction can be calculated.

Benzene (relatively inert to direct ozone oxidation, takes 10^3-10^4 sec) required 5 g O_3 decomposed/m^3 (10^{-4} moles/ℓ) for 37 percent elimination at pH 8.0. At higher pH levels, more decomposed ozone was required as free ammonia and carbonate ions competed for the $OH^{\cdot}$ radicals.

A.2 Paper No. 52: "Rapid Appraisal of the Effects of Various Substances on Microorganisms," by P. H. Brouzes, A. DePierrefeu, J.-Y. Bernhard, C. Racle (France)

This study by I.R.CH.A. researchers in France concerned an apparatus to measure the response of a biological system to an imposed waste feed. Cultures are maintained in aerated reaction vessels (2 to 35 ℓ) which are fed with a suitable material at 15 to 45 min intervals at a dilution rate of 0.25 to 6/day. The DO level is frequently monitored and a plot of the oxygen depletion and rise subsequent to each feeding allows a determination to be made as to when steady state is reached.

One of these cultures is then fed into a 100 mℓ measuring cell into which the test feed is added. A 4 min period is allowed to establish an endogenous oxygen uptake rate and then 1 mℓ, 2 mℓ, 4 mℓ and 8 mℓ injections of feed are made at 2 min intervals. This sequence is repeated every 30 min. Oxygen uptake is displayed on a cathode tube, is recorded, and is monitored by a computer. The rise or fall in uptake rate upon successive feedings shows activation or inhibition.

Tests can be run before and after acclimation and at various concentration levels. Studies were reported on formaldehyde using microorganisms acclimated to a brewery waste, 50 products used in the brewery industry, silage liquor from potato haulm, paper pulp wastes, gelatin industry waste, and landfill leachate. pH can be recorded simultaneously with oxygen uptake to follow acid degradation.

A.3 Paper No. 55: "Immediate and Continuous Measurement of Activated Sludge Quantity in Sewage Biological Treatment Tanks," by J. Durot (France)

J. Durot of Degrémont in France described a new (to this field) approach of measuring the concentration of activated sludge in a reactor. Manual methods had proven to be too slow for guiding decisions as to wasting of biomass. Existing automatic measurements were either insufficiently sensitive, subject to plugging, or dependent on the quality of the sludge or interstitial liquor.

The new technique measures the weight deviation between a given volume of mixed liquor and the same volume of interstitial water obtained after removal of the suspended solids; this weight deviation denotes the apparent weight of suspended solids in the interstitial liquor. After calibration, accuracy is about 10 percent over a range of "1000-8000 mg/dm^3."

In the instrument, mixed liquor flows slowly from top to bottom through a vertical tube having a constant upper level. Near the upper and lower ends of the vertical tube, two side tubes are connected. Since the solids settle out of these side tubes, the liquor is lighter and rises to higher levels. The differential levels in the three tubes are ultrasonically detected. This differential is converted to a solids concentration using calibration curves gravimetrically developed for various volatile solids fractions.

Several months of operation of the instrument at two sewage treatment plants have shown good correlation with gravimetric measurements. Wasting duration and frequency are controlled through a central computer. Further studies are needed to reduce size, cost ($20,000) and servicing needs of the instrument before it can be used at smaller plants.

A.4 Paper No. 58: "Wastewater Control Technology in Steam-Electric Power Plants," by T.-T. Chu, P. A. Krenkel, R. J. Ruane (USA)

Thermal discharges are a well known concern of steam-electric power generation. However, chemical discharges have been studied over the past 10 years as reported in this paper by TVA engineers. Characteristics and treatment of six major waste streams are described in detail:

1. Ash pond effluents
2. Boiler blowdown
3. Chemical cleaning wastes
4. Coal pile drainage
5. Cooling tower blowdown
6. Wet scrubber wastes

The key factors influencing contaminant level were identified. Treatment alternatives ranged from high cost reuse schemes to routing many streams through the ash disposal pond.

Data not in the preprinted paper were presented on metals disposition between the fly ash, bottom ash, scrubber water, mist eliminator, and gaseous effluent. Hopefully, these data can be published soon.

B. Prepared Discussion

B.1 Paper No. 49

Kavanaugh (USA) stated that this paper by the EAWAG researchers provides kinetic data and a model permitting evaluation of the effectiveness of ozonation without necessarily going to pilot studies. The paper appears complex and difficult to read but is packed with information and is well worth study. Kavanaugh pointed out that the term "elimination" means loss of parent molecules and that perhaps "oxidation" or "transformation" would have been better. Also, kinetic data for all steps of parent and daughter compounds would have been useful, at least for one compound. The author responded that aldehydes are formed in lake water oxidation; these persist for about 1000 sec. The discussion also pointed out that yield factors were dependent on the chemistry of the system, that a critical assumption as to rate constant had been made, and that ionic strength could be an important factor in reaction kinetics. Discussers also asked about data on humic substances. The author responded that oxalic acid was the product and it was stable.

B.2 Paper No. 52

Chalmers (UK) pointed out that the approach of using oxygen uptake to monitor biological systems was not basically new but the speed of data availability is the valuable contribution of this paper, presuming such speed is really needed in a given situation. The speed of the method justifies use of the digital computer.

A concern was expressed that with the lag phase of microorganism growth, this fast measure of response may be unnecessary. The author responded that a 10-fold increase in oxygen uptake can occur immediately after injection. The period of the test is 30 min which provides suitable warning as to the need for physical-chemical treatment.

B.3 Paper No. 55

Markkanen (Finland) commented that the pulp and paper industry had used a similar differential-level instrument for measuring suspended solids with results that were not always satisfactory, but suspended solids levels were higher. In response to an expressed concern over several potential sources of systematic errors, the author counseled that 1) samples should be taken only where the liquor is rapidly circulating, 2) the liquor should be degassed with a retention time of 10 min to avoid air bubbles, 3) the liquor should be mechanically treated to avoid grit, 4) if lighter solids rise in the side tubes, the ultrasonic detector is affected due to echos (cleaning of the tubes avoids this), and 5) limit of measurement is 10 g/ℓ due to clogging problems.

B.4 Paper No. 58

Lever (South Africa) emphasized the enormous amount of pollution emanating from steam-electric power generation in South Africa even with controls. Laws there prevent converting an air pollution problem into a water pollution problem. Scrubbing for sulfur oxide removal causes problems with wet, cool gases as opposed to the original dry, hot, more buoyant gases. The author pointed out three additional problems from scrubbing: acid rainfall, sulfate formation, and sludge disposal.

In South Africa power stations are constructed at the mine face in remote areas. Dry cooling (as opposed to evaporative) systems are used, so there is no cooling tower blowdown and no associated problems of disposing of biocides. The author responded that TVA is studying dry cooling systems for new power stations in certain areas.

C. Floor Discussions

C.1 Paper No. 49

In response to Ramaden's (Egypt) question on the effect of suspended solids on ozonation, the author stated that tests after filtration and with particles provided the same results. In regard to ozonation economics, the author cited a dependence on the contaminant, e.g., if phenol, amines, and color are present, these are selectively and directly oxidized.

Dean (Denmark) remarked that when water is clean, ozone is reported to remain as a residual in the distribution system. Perhaps peroxy compounds are really present and then react positively in the ozone test but don't disinfect. The author felt that bicarbonates react with these other peroxy compounds, also.

Hart (South Africa) asked, since ammonia and bicarbonates act as free radical scavengers above pH 8.0, what pH should be used in a reclamation system? The author replied that when a high selectivity is needed, keep the pH as low as possible. When low selectivity is desired, use a relatively high pH - but remember that with indiscriminate oxidation, a relatively clean water is needed due to economic considerations.

Neytzell-DeWilde (South Africa) asked if nitrosoamines are formed? The author replied that the reaction starts with an amine and splits off ammonia. This is the rate-determining step, the remainder is 1000 times faster.

C.2 Paper No. 52

Grabow (South Africa) pointed out that biological systems are vital to wastewater treatment as the capabilities of physical-chemical systems are more limited. So, the reported studies on monitoring biological units are most valuable. He stated that some microorganisms can revert to anaerobic metabolism when stressed and queried whether this could be detected. The authors are studying that aspect now.

Matsche (Australia) suggested that thiourea be added to inhibit nitrification at times, which would allow distinguishing between nitrogenous and carbonaceous oxidation.

Moreau (France) reported that he was setting up an apparatus based on the principle described in this paper. He would use it for all the reactors at a wastewater treatment plant and monitor upstream water to predict how it should be treated and whether physical-chemical measures need to be taken. Oxygen requirements also can be predicted. A computer is needed for practical application.

C.3 Paper No. 55

There was no floor discussion.

C.4 Paper No. 58

Hrudey (Canada) expressed a concern over organic discharges from steam-electric power generation, especially from the coal pile. The author responded that much of the organics wound up on the solids.

Stone (USA) inquired about groundwater pollution from the ashes. The author stated that a report was to be issued soon on metal balances around two ash ponds. A side study had been conducted on the attenuation effect of solids. Leachate from scrubber-sludge ponds is also being monitored.

D. Other Observations and Comments

The response of the authors of the various papers to discussers' questions have been incorporated in Sections B and C. The high concern over better understanding and control over physicochemical and biological treatments was enhanced by good attendance and generally lively discussions at this session.

In regard to Paper No. 55 on measurement of mass activated sludge, some comments after the session concerned an alternative practice by some in the United States of using a total organic carbon measurement after sample homogenation to measure biomass. This approach had not been mentioned in the paper. Also, the proposed technique only measures mass and not viability or activity, which also are very important. Perhaps a combination of the systems in Papers No. 52 and 55, with simplifications, will be needed.

IV. CRITIQUE OF SESSION

The papers in this session advanced the field of water pollution control from different perspectives. Original, basic contributions to knowledge of the ozonation process were made. Fundamental phenomena were identified and quantified. Lively discussions pointed toward additional research efforts. The two papers on biological treatment were not of a fundamental nature, but do provide refined, faster approaches to measuring the activity and quantity of biomass in these important systems. Both studies showed in-depth analyses of the problem and feasible solutions. The paper on steam-electric power generation wastes was of a broader nature in that problems were identified and characterized and some alternative solutions enumerated.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The studies reported in this session encompassed fundamental process research, operational aids, and the characterization of a particular type of industrial waste.

The paper by the EAWAG researchers on ozonation (Paper No. 49) clearly should be studied and utilized by Americans working in the physicochemical treatment area. It brings quantitative information to bear where only qualitative findings have been available. The effects of pH and various organic and inorganic solutes on the ozonation reactions were clearly defined. For example, ways of keeping ozone undissociated to better effect disinfection or a specific organic oxidation are defined. This research should be built upon by others. Several additional research areas were posed by the formal discusser.

The two papers (Nos. 52 and 55) by French scientists on biological treatment present interesting approaches toward better operational control of such systems. Means of monitoring systems response to an imposed feed condition through oxygen-uptake measurement were described. Results are monitored by a computer. The biosolids level in the reactor can be monitored by a sensitive density measurement in a novel apparatus. There is much research in the United States on control models, but much less on the basic measurements to be used in these models. These papers provide valuable input in that area. Further study should result in simplified systems. The oxygen uptake apparatus also can be used as a laboratory system to study new waste streams or products proposed for discharge to a biological waste treatment system.

Paper No. 58 by TVA engineers brings to light a major industrial waste area that is not discussed as often as some. Waste streams from various sources in steam-electric power generation are characterized and treatments proposed. This organization of data, insights, and ideas should help the industry and regulatory agencies to better understand and solve the identified problems.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: C
Time: 9:00 am to 12:30 pm

B. Theme of Session: Management of Nonpoint Pollution

II. REVIEWER

A. Name: Bernard B. Berger

B. Position and Affiliation: Director, Water Resources Research Center
University of Massachusetts
Amherst, MA

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 50: "A Study of Stormwater Runoff Quality," by W. G. Characklis, P. B. Bedient, F. G. Gaudet, F. L. Roe (USA)

This paper presented the results of a three-year sampling program designed to determine the effects of rainfall on the quality of runoff from four types of land use: undeveloped forest, developing forest, fully developed residential, and mixed commercial-residential. The locus of the study was four watersheds in the Houston, Texas, area, two within the metropolitan area and two in an outside planned community, Woodlands. The study's objective was to evaluate the water resources component of an environmental protection plan developed by the architects of the planned community and to recommend a management plan that would assure protection of the quality of surface and groundwaters and associated ecosystems from the pollutional effects of storm runoff. The study included examination of rainfall quality and dry fallout, land use, and the influence of natural and man-made impoundments. The importance of groundwater supply was emphasized because of its influence on soil moisture and, therefore, on the character and the extent of vegetation. The quality of rainfall per se was found to be important in respect to concentration of nutrients and organics. Not unexpectedly, the authors reported that the factor of imperviousness was the major determinant for character and degree of pollution load; lake storage was a major factor in controlling sediment discharge. The preliminary water management plan as presented calls for the following: 1) induced infiltration for groundwater recharge; 2) use of the system of man-made and natural lakes to capture water for sediment and flood control; and 3) use of tertiary treated sewage effluent to maintain water levels during dry weather.

A.2 Paper No. 53: "A Mass Balance Method for Estimating Combined Sewer Runoff and Overflow Quality from Sewage Treatment Plant Data," J. A. Mueller, A. R. Anderson (USA)

This paper described a procedure for supplementing the normally scanty data base on quality of storm runoff by exploiting the existing long term record on influent quality at the sewage treatment plant. This procedure provides data on urban runoff and combined sewer overflows and on pollutant load by use of flow records and pollutant analyses routinely conducted at the sewage treatment plant. The procedure employs a model which integrates daily data on sewage flow and mass contributions of pollutants over the sampling day. Runoff volume is estimated from rainfall data obtained independently for each day of rainfall. The paper suggested that many communities are in a position to extract value from water quality data routinely acquired over the years. The locus of this study was New York City's 26th Ward Water Pollution Control Plant where 30 years of data have been recorded. A check of predicted values against actual overflow data for parts of the test area showed close confirmation. A high degree of correlation was found particularly between runoff suspended solid load vs. rainfall volume. The authors conclude that while the procedure is rough, it can provide much valuable data. They state that the major application of the procedure would be to areawide assessment on a relatively large time scale to get accurate information on yearly contributions of pollution by runoff and combined sewer overflows.

A.3 Paper No. 56: "Comparative Assessment of Pollution Loadings from Nonpoint Sources in Urban Land Use," by V. Novotny, J. Goodrich-Mahoney (USA)

This paper focused on ways to protect Great Lakes water quality from pollution by nonpoint runoff. The paper rejected the assumption that the character and intensity of nonpoint pollution may be acceptably predicted from knowledge of land uses and from use of generalized unit loadings of pollutants for each land use. In effect, therefore, conventional models are rejected as oversimple and predisposing to gross error. To avoid such error it is necessary to examine the basic processes that generate pollution from diffuse sources. The authors stated that in urban areas major sources of pollution are atmospheric fallout, street litter deposition, animal and bird fecal wastes, dead vegetation, and road traffic input. The factors influencing the quality of runoff include land use, population, traffic flow and intensity, street cleaning practices as related to street surface type, and nature of pollutants. The authors further describe some 10 factors that influence unit loadings and state that most of these factors derive from land use. Proceeding from this basis, they state that a multi-dimensional loading equation for various land uses may be based on two independent variables in addition to land use: dry fall-out and street cleaning practices. In non-urban areas the authors state that it may be assumed that significant pollution is usually associated with sediment. They describe a pollutant delivery prediction model that is based on the product of the quantity of sediment released in a storm event as determined by the Universal Soil Loss Equation and a "delivery ratio factor." This product presumably represents sediment loading in the receiving water body. Loadings of specific pollutants are determined by the product of the sediment released, delivery ratio factor, pollutant content of the soil, and an enrichment factor which accounts for the difference in pollutant content of the soil and that in the suspended sediment. In all, the determination of pollutant delivery to the water body involves consideration of eight variables: rainfall, soil erodibility, length-slope, soil cover, erosion control practice, delivery ratio, soil pollutant content, and the enrichment factor. By use of assumed values for each variable or of values calculated from functions developed by earlier investigators, a simulation overland flow model was developed to estimate loadings for a number of different land uses. Estimates so derived agreed well with data obtained by monitoring in the Menomenee River watershed. The authors believe that the simulation model so developed provides a useful tool in the design of measures to reduce pollution from nonpoint sources.

A.4 Paper No. 59: "Design of Teacup Solids Separators for Treatment of Sewer Overflows," by K. D. Kerri, A. L. Prasuhn, G. E. Wilson (USA)

This paper described the Teacup Separator, a device proposed for separating solids in combined sewer overflows and in storm sewer discharges. The operation of the Teacup Separator derives from two independent velocity profiles induced within the Teacup. One is a forced vortex velocity profile characterized by constant angular velocity in which solids with specific gravity greater than twice that of the suspending fluid move through the free vortex field at the center of the Teacup to reach the periphery of the vessel, eventually to be deposited at the vessel's bottom near the center. This is essentially the principle of the cyclone separator. The other is the free vortex velocity profile which is characterized by constant vortex strength which the authors stated is equivalent to a conserved angular momentum. This is manifested by a pressure gradient with increase outward from the center. This pressure gradient induces solids with specific gravity less than twice that of the suspending fluid to move toward the eye of the vortex, that is, to the center of the vessel. Floatables move very rapidly to the center, there to rise and be removed. Each field may be regulated separately. The elements of the Teacup Separator may be sized to accommodate specific flows and types of suspended solids. Design criteria apply to inflow velocity, discharge velocity, diameter of unit, height of unit, and underflow diameter. Design is facilitated by the use of dynamic similitude flow studies using the Froude number as the basis for determining dimensions of unit elements. Using this procedure, a 0.25 m model accurately predicted the performance of a 1.5 m diameter Teacup serving a sewage flow of about 0.25 m^3/sec. The same procedure is applicable to design of a Teacup for any magnitude of combined sewer overflow or storm sewer discharge.

B. Prepared Discussion

B.1 Paper No. 50

Orhun (Turkey) commented on the use of models for predicting the pollutional effect of storm runoff. Orhun stated that all models must recognize that a pollutant is conveyed by convection, diluted by turbulent dispersion, and changed by physical, chemical and biological conditions, for example, the initial concentration of a pollutant of concern. He noted that it is relatively easy to develop a model for a point source of pollution but not so easy for a nonpoint source. The fact is that the initial concentration of a pollutant changes as a function of time and also that rainfall and stream flow are characterized by time functions. Consequently studies of storm runoff should emphasize the perspective of mass continuity. This means that input has to be viewed as a mass load per unit time. Because area and rainfall intensity are major parameters of concern it would be appropriate to present data in terms of mass load per unit of rainfall per unit of area. It is incorrect to base analyses solely on concentration of pollutants. The point of this comment was not clear. The authors' key tables and graphs present data in terms of loadings. The authors are perhaps wrong in comparing stormwater and sewage effluent in respect to the impacts on water resources. Also, the authors should be careful in extrapolating conclusions on storm runoff given the uncertainties and the lack of statistical rigor in the data.

B.2 Paper No. 53

Ellis (UK) reported that the Greater London Council has investigated mathematical models with three particular objectives: 1) determine operating conditions of the sewer system that are appropriate to various storm conditions; 2) determine optimum setting of weirs and penstocks to enable maximum use to be made of treatment plant and storage capacity; and 3) assess the effects of system modifications such as balancing tidal river and sewage inflows and outflows. The first major problem encountered was that the cost in developing and utilizing the model would be prohibitive. Can the author say something about the cost effectiveness of the system investigated in New York City? The second major problem related to the difficulty in programming the model to assess the effects of local heavy storms. It was determined that the time necessary to run the computer model was such that the storm would have passed before useful results could be made available. Apart from these problems, a question is raised regarding the multiple regression equation the author presented for predicting suspended solids load. The equation is based on storm interval and duration although the highest correlation was found to be based on rainfall volume. Why was volume excluded from the equation? In this connection, it is noted that suspended solids in urban runoff was related primarily to scouring of deposits in sewers. One should note that engineering conservatism would demand that models always be supported by carefully calibrated sampling programs. This may inhibit full scale use of models in the near future.

B.3 Paper No. 56

Viljoen (South Africa) described the status of pollution control in South Africa indicating that his country is still concerned primarily with the correction of point sources. However, the importance of nonpoint sources is realized, particularly in the Pretoria-Witwatersrand-Vereeniging region, where the need for water reuse is urgent and where the Rand Water Board is making a comprehensive survey of all sources of pollution. The following questions were directed to the authors:

1. Nutrients, metals, organics, bacteria and sediment were described as important pollutants, but the model presented was concerned only with suspended solids and phosphates; was there a reason for this?
2. The simulation model was calibrated in a period of 12 to 24 months; was this sufficient period for calibration?
3. What thoughts do the authors have on further revision of the simulation model?

B.4 Paper No. 59

Roberts (UK) pointed out that one should exercise caution in using laboratory-scale experiments for the design of field-scale units, since the difference in scale can transform success at one level to failure at the higher level. In this connection, it appears that the tests cited were limited to carrot washing operations and to waters containing soil particles of known characteristics. Because the sewage plant tests cited were of short duration, they perhaps should not be considered representative or reliable. In this connection, one should inquire whether raw sewage was actually used in the tests since rags in the sewage, unless screened out, could destroy the effectiveness of the unit. Field trials are obviously important in testing new equipment, but one should recognize that storms vary in character from watershed to watershed, and sewage character varies with duration of the storm. This raises a question as to whether it is possible to design a Teacup Separator that may operate satisfactorily throughout the storm, bearing in mind that changes in solids will occur. If the Separator effectively intercepts and treats the first flush of the storm, or the combined sewer overflow, it would obviously provide a very valuable tool for the designer of sewage systems. In this connection one might ask what the head requirements are for the operation of the Teacup Separator, and whether head may be expected to be available at all times. What is the head loss in the Separator? How are parallel systems of Teacup Separators to be achieved in practice?

C. Floor Discussions

C.1 Paper No. 50

Ellis (UK) stated that the author emphasized the importance of recharging the groundwater supply with stormwater. Is there not a danger that carcinogenic substances might reach the drinking water supply as a result of such recharge? Would the author also comment on why his plots of cumulative runoff frequency curves presented in Figure 5 are all concave. Work in the United Kingdom shows they vary from concave to convex.

Berger (USA) requested the author to say something about the institutional framework in which this study was organized and is being conducted. Who is paying for it? What role, if any, has the State of Texas played in the design and conduct of the study? How will the results be used?

Grabow (South Africa) expressed satisfaction in the wide range of microorganisms used to evaluate the bacterial quality of the waters of interest and the effort to use the right microbial indicator for the right purpose. In this connection, the author was asked to provide information on the basis of decisions for employing the microbial indicators actually used in this study. The failure to include viruses in the microbial studies was noted with disappointment.

Pfisterer (Germany) expressed doubt in the validity of the linear relationship between precipitation and pollutional load depicted in Figure 6. The data were stated to be too scanty, only a few data points being shown. It was stated further that with only three values to establish a linear regression one would always get a correlation greater than 0.95. Many important inferences could be obscured by the assumption of a linear relationship under such conditions.

Author's Reply - In response to Pfisterer, Characklis stated that the linear plot was presented because there were in fact so few data points. New data elsewhere indicate that the relationship is log-linear, not linear. In response to Grabow, he stated that the study design provided no capability to undertake analyses for virus. With respect to use of specific microbial indicators, puzzling results were encountered. For example, finding of high concentrations of salmonella organisms in the drainage of forested watersheds was difficult to understand and remains to be explained. In response to Berger, Characklis stated that the State of Texas played a negligible role in the design and conduct of this water resources study. In fact, Texas did not enter into the project at all. The project, a three-year study at a total cost of one million dollars, is supported to the extent of 60 percent by EPA. The architect-developer of the planned community at Woodlands provides 30 percent of the supporting costs, and Rice University 10 percent.

Ludwig (Brazil) pursued the question concerning the role of the State of Texas, asking how the state which has legal responsibilities in water resources management and in nonpoint runoff control could just ignore the project. Characklis noted that the state had discharged its legal responsibilities by issuing a permit for the tertiary wastewater treatment system. Presumably the state had been involved in some way in the approval of the development of impoundments, but the state had actually no role in that component of the overall job described in the study. In response to Orhun, Characklis noted that the study team was encouraged to use the EPA stormwater model at Woodlands even though the drainage system here is quite different from those for which the EPA model was developed. The shortcomings in the application of this model are recognized but the study team lacked the resources to develop its own modeling effort. The study team recognizes that there are many important variables that are not effectively dealt with in the EPA stormwater model but under the circumstances there was little it could do. Characklis concluded his response with the comment - we must be careful that we do not come up with the equivalent of a mechanical end-of-the-pipe solution to the nonpoint problem. We should give attention to common sense solutions including use of green areas and marshlands.

C.2 Paper No. 53

Deutsch (France) requested the author to say whether there have been changes in land use during the 30-year period studied and whether these changes have been reflected in runoff volume and quality.

Orhun (Turkey) urged caution in establishing correlations, particularly in the correlation of mass loads to rainfall since the author's data on scouring of dry weather solids in sewers could produce misleading interpretations.

Characklis (US) stated that a number of questions are pertinent with regard to use of correlations. Studies conducted in connection with the Woodlands planned community in Texas, for example, have shown no consistent relationship with respect to BOD_5 within a watershed at different periods of a storm, from storm to storm, or between watersheds. BOD_5 provided no useful insights and was eliminated as a parameter. One should keep in mind the overall uncertainty in using data acquired through use of models in predicting the impact of stormwater quality on the environment. In this connection, would the author comment on the environmental effect of a transient phenomenon like a storm.

Goettle (Germany) stated that the temptation to convert theories to guidelines should be fought. The paper is unusual in that it examines a long-term data record whereas most studies on storm runoff are characterized by short-term data collection but there are dangers in long-term records. For instance, measuring techniques may change over a 30-year period and analytical methods may also undergo change. Beyond this, the statement that linear correlation of data is sufficient and that it is not necessary to inquire further can be misleading. It appears that many investigators in the United States do not seem to favor fundamental assessments in evaluation. For example, investigators in the United

States often simply relate runoff flow to pollution loads. What happens if we have a rainfall event that is intensive but short and, therefore, of small volume? U.S. investigators are urged to rethink their procedures.

Author's Reply - The cost of running the described model is negligible. The operation of the model requires very little computer time. The possibility of error in data interpretation resulting from changes in analytical method was examined through study of trends of monthly averages or pollutant loadings over the study period. No significant error was discerned. Similarlv, the influence of land use changes on pollutant loadings was examined by relating physical changes (including sewer extensions) to pollutant loadings and found not significant. In determining the relationship between pollutional character of runoff and duration of and interval between storms, runoff quantity was not used directly because it is already included in the flow factor used in computing pollutional loading. No correlation was found in the analysis of concentration and storm intensity; however, significant correlation was found between loading and storm intensity. There appears to be no fundamental reason for such a relationship, but when we analyze the data the relationship is there. When we get into the evaluation of the model on shorter time scales, we hope to see a lot of the variability removed by considering other factors such as intervals between storms and storm duration. If no fundamental relationship emerges, we'll resort to use of statistical functions. Sampling programs to serve the purpose of engineering conservatism are needed. In this context it should be borne in mind that the sewage treatment plant constitutes another sampling point in the system since the discharge of the plant can be equated to a combined sewer overflow. (Goettle's criticism with regard to an apparent prediliction on the part of U.S. investigators to produce measurement data rather than to seek to establish an understanding of the fundamental nature of a process of interest was left unanswered and hanging. The question is examined in Section IV.)

C.3 Paper No. 56

Desbordes (France) noted that the author presented a complex deterministic model that included some eight sub-models. At least 20 parameters and probably more were used. This suggests a number of questions, among them the following: How many events were used in testing the model and what was the duration of model testing? Were studies made on the sensitivity of the sub-models? What was the cost of the study? The soil erosion sub-model used in this study is some 50 years old; is it valid? What about verification of the other sub-models used in the overall model?

Young (UK) observed that the model apparently is based only on pollutants that are related to sediment transport and the remedial measures proposed are also so related. What about other pollutants? Was any attempt made to relate important pollutants more closely to some of the land uses described and applying appropriate remedial measures to these specific areas, or was the strategy based solely on total sediment from the entire catchment area?

Wallace (Australia) said that one sometimes has little opportunity to make site specific studies to determine specific loadings and, therefore, is forced to select data from the literature on average annual loadings of plant nutrients that seem to be applicable. It is quite possible that these values may be misleading. Would the use of average annual export rates of plant nutrients over- or under-estimate actual loadings? Is the error so serious as to require specific studies?

A discusser from Germany made what appeared to be an important criticism in referring to a practice of withholding information on new models by industry and engineering firms until a proprietary relationship could be established. (The criticism did not come through clearly because of vagueness of the translation.) The discusser also stated that on the basis that models should be as simple as possible, the model presented by the author, which included some 20 or more parameters, would hardly make for efficiency. The discusser stressed the importance of establishing reliable initial values for parameters and the associated time functions and stated that the values in the paper appeared to have been taken from the literature. If this is the case, he stated, the model presented by the author could hardly be considered an improvement over existing models.

Author's Reply - The model does have some 20 parameters, but like most models it is sensitive to only a few. These include "depression interception storage," permeability, slope, vegetation cover, and the variables used in the Universal Soil Loss Equation. The authors have been calibrating and verifying the model with specific storms. There were three design storms so used, one of low intensity, one of medium intensity, and one of high intensity. The results of the medium intensity storm correlated well with those of the high intensity storm. The results of the low intensity storm did not correlate well with those of the medium or the high. The model, therefore, appears not to be sensitive to low intensity rainfall. With regard to the use of the 50-year old Universal Soil Loss Equation, the authors have found it reliable and see no reason not to use it. With regard to the emphasis on sediment and not on important pollutants unrelated to sediment, the paper reported on only a small part of the comprehensive research programs underway in the Great Lakes. Research not reported here is being directed to PCBs and other important pollutants. With regard to whether the model over-estimates or underestimates contributions of pollutants, three years of monitoring data on the Menomenee River indicate good correlations except for the fall period. The simulation model gives average data for this period, but monitoring data show essentially zero loading of pollutants. The author's assumption is that monitoring data in the critical fall period of the year tends to underestimate actual loadings.

C.4 Paper No. 59

Ludwig (Brazil) noted that the paper states that the Teacup Separator should achieve between 50 and 100 percent removal of floatable solids. However, the results of the operation of the Teacup Separator at the Sacramento sewage treatment plant do not include any information on floatables removal. Would the author explain this and also would he define the term "floatable solids."

Dunkers (Sweden) said the Teacup Separator might be classified as a mechanical device that provides the same function as gravity separators. It is, therefore, appropriate to ask whether it would be effective in the removal of chemical flocs. This would be of keen interest to countries like Sweden which are considering chemical treatment of heavily polluted stormwater.

Fouquet (France) noted that there is interest in France in a separator very similar to the Teacup Separator, and has set up a pilot plant which gives results that are in good correlation with those reported by the author. The unit is a realistically sized one with a diameter of 12 m and is set up in the Paris region. It is handling a flow of 3 m^3/sec. The results, yet to be reported, are real world results.

Author's Reply - The authors experienced precisely the kind of problems described by Roberts with grease and rag plugging. Difficulty was also encountered in determining mass balances. For example, the inflow showed a small amount of grease but underflows showed substantial quantities. This may reflect early sampling problems. The authors believe they have solved the grease, rag, and mass balance problems and that the Separator can handle prolonged flows as well as the heavily polluted flows characteristic of first flushes. Responding to Ludwig's question concerning floatables, these are determined on a volumetric basis. A 30 min holding period is used. In the Teacup Separator, floatables move in the direction of reduced pressure and, therefore, move to the center of the Separator where they rise. The pressure differential at the discharge end produces a syphon-like action which effectively removes the floatables from the system. The question raised by Dunkers with regard to the utility of the Teacup Separator in the separation of chemical flocs is of particular interest. The authors have yet to examine this question, but believe the Teacup would perform satisfactorily. The U.S. investigators are, of course, keenly interested in the work being done in France and look forward to the results that will be reported by Fouquet.

D. Other Observations and Comments

Each of the four papers at this session reflected a pragmatic effort to come to grips with the nonpoint pollution problem. Paper No. 50 represented a well conceived program directed to the design of a system of control of storm runoff and its associated pollution as a component of a comprehensive land development plan. Paper No. 53 recognized the potential value of the immense body of data on water quality and sewage flow at the sewage treatment plant and sought to determine how this long-term investment in data acquisition could best be used in evaluating the combined sewer overflow and storm runoff pollution problem. Paper No. 56

rejected as oversimple the conventional predictive models for evaluating nonpoint pollution contributions and set itself the difficult task of identifying all major influences operative in a given area, and fitting these factors in a complex but reliable model for making such predictions. Paper No. 59 presented a new and promising device for separating settleable, suspended and floating solids in combined sewer overflows and storm sewer discharges. Floor discussion indicated that the problem is of world-wide interest. Those who participated actively in the discussion included individuals from the United Kingdom, Germany, France, Sweden, Australia, Turkey, and South Africa.

IV. CRITIQUE OF SESSION

A surprising and perhaps unfortunate feature of this session was an arrangement such that all four papers originated in one country - the USA. This, I would assume, is unprecedented. Perhaps it was done deliberately but, if so, the reason was not apparent, particularly since papers on various aspects of nonpoint pollution prepared by investigators in other countries were presented elsewhere in the program. In any case, the discussion brought out clearly that research of considerable interest is underway in the UK, France, Germany, and Sweden. One may assume that research is also being conducted in other contries, including South Africa and Canada. A rather harsh criticism with respect to the work of the U.S. workers was contained in a comment made by a German national (see discussion of Paper No. 53). He suggested that U.S. research workers are perhaps too quick to publish their research results; that in particular the models described do not reflect a due concern with the need to understand fundamental aspects of phenomena of interest, and that too many U.S. papers are characterized by a mass of measurements. He suggested further that U.S. research workers should "rethink" the nature of their projects. This appears to be an important criticism. It is clear, however, that any such generalization is entirely too sweeping and probably it would be hard to confirm; there would be too many exceptions. The fact is that many complex phenomena are understood in the sense that a non-quantitative description of the process may be presented. The complexity is in developing and proving the mechanistic model. This is almost always time consuming. In any case, the term "fundamental understanding" is relative and sometimes vague. One need hardly argue the point that there is a world of precedent supporting the prudent use of statistical functions in the interpretation of natural phenomena.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Since all four papers of the session described research in and by the United States, and with the possible exception of the Teacup Separator, were supported in part with public funds, it appears that a basic intent is application of the research results to solve U.S. needs. However, the discussion indicated that important related research is going on elsewhere, particularly in the UK, France and Germany. One may assume that the U.S. investigators participating in this session will establish an effective communication with the workers in other countries who identified themselves at this session.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: A
Time: 2:00 to 4:15 pm

B. Theme of Session: Chemical Precipitation and Tertiary Treatment

II. REVIEWER

A. Name: C. P. Huang

B. Position and Affiliation: Associate Professor
Department of Civil Engineering
University of Delaware
Newark, DE

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 60: "Trace Metal Removal from Secondary Effluent by Two-Stage High Lime-Magnesium Treatment," by E. Idelovitch, M. Michail (Israel)

The paper dealt with a pilot plant study involving a 0.1 mgd wastewater flow for the removal of trace amounts (< 500 μg/ℓ) of heavy metals, e.g., Cd, Cr, Pb, Cu, Zn, Ni, Fe and Mn, from the effluent of oxidation ponds by two-stage high lime-magnesium treatment.

The pond effluent was first treated with a high dosage of lime to raise the pH values from 8.5-8.3 to 11.0-11.8 and with magnesium chloride (40-50 mg/ℓ) in a steel tank reactor (3.66 m diameter, 3.26 m height) for 2 hr, followed by a series of polishing ponds (7 excavated basins with a total area of 1700 m^2, a total operating volume of 1500 m^3, and a detention time of 7 to 14 days) for natural recarbonation and ammonia stripping to take place.

The percentage removal efficiency of the high lime-magnesium process alone showed the following increasing order: Pb (24) < Ni (26) < Cd (35) < Cr (43) < Zn (49) < Cu (50) < Fe (60) < Mn (82). By detaining the high lime-magnesium treated effluent in polishing ponds where recarbonation brought the pH value down to 10.0, further removal, except Fe, and especially Cd, Cr, Pb, and Zn, was observed. The overall percentage removal efficiency was best obtained for Mn (88), Cr (66), and Zn (60) by the combined high lime-magnesium and polishing ponds treatment. The removal efficiency increased with increasing influent concentration. Precipitation of metal hydroxides and adsorption of metal ions onto magnesium hydroxide were postulated as removal mechanisms. However, the concentrations of Cu and Pb in the effluent were higher than those predicted from solubility products of pure hydroxides, while the concentrations of Cd, Zn and Ni were lower than those predicted from the solubility products of these metal hydroxides. This was attributed to the formation of Cu and Pb chelates that render both metal hydroxides more soluble.

Generally, the residual concentrations of heavy metals obtained by high lime-magnesium treatment combined with recarbonation ponds, as well as by high lime-magnesium treatment alone, are below limits imposed by the WHO's 1971 drinking water standards. The effluent concentrations of heavy metals also meet regulations for unrestricted irrigation of all agricultural crops in all soils.

A.2 Paper No. 63: "Domestic Wastewater Treatment with Oxidation Ponds in Combination with Chemical Precipitation," by P. Balmer, B. Vik (Norway)

Balmer reported on a Norwegian experience with pilot and full scale plants on phosphorus removal by alum precipitation. In pilot plant studies, three modes of combining oxidation pond treatment and chemical precipitation were investigated. These three modes were 1) pre-pond precipitation, 2) in-pond precipitation, and 3) post-pond precipitation. Each mode was operated at three levels of detention time associated with the oxidation pond at 4, 12 and 40 days, respectively. In full scale operation, alum at various amounts, ranging from 80 - 150 mg/ℓ, were added to influents of three separate pond systems; namely, Losbye (18 days detention time, one pond), Kjellerholen (9 days detention time, one pond), and Nordseter (1.2 days detention time, three ponds). Alum was directly added to the influent, except at Nordseter where alum was added to the effluent from the first pond.

The results from pilot plant operation indicated that chemical precipitation significantly reduced the concentrations of phosphorus independent of mode of alum application. The phoshporus removal efficiency was not affected by the mode 2 operation; the mode 3 treatment was the most sensitive to detention time. The extent of sludge accumulation in pond was lower in mode 1 and higher in modes 2 and 3. Post-pond and in-pond precipitation resulted in some degree of sludge accumulation. Adequate detention time was important to keep the pond aerobic. All three different combinations of chemical precipitation with oxidation ponds gave good treatment results. With a properly designed pond, winter results would be at least as good as those achieved in the conventional chemical precipitation plant; the summer results might be equal to conventional biological plants with post-precipitation. Post-pond precipitation gave the best effluent with least algal mass. Pre-pond precipitation tended to reduce the available pond area quickly.

It was also suggested that two primary ponds with alternating operation be used so that one pond could be drained for sludge removal while the other was in operation. Their experience also indicated that there should be at least one pond following the pond receiving the precipitants.

The treatment efficiencies in terms of phosphorus, nitrogen, COD, BOD and suspended solids removal experienced with full scale operation were generally promising, in the neighborhood of 80 percent for all. Oxidation ponds have been found to be a feasible alternative for small communities.

A.3 Paper No. 66: "Improvement of Quality of Waste Pond Effluents in Northern Area by Chemical Precipitation," by J. U. Airaksinen (Finland)

The paper, read by Puolanne, stated that in Finland the total number of wastewater treatment facilities as recorded in 1975 was 504. Roughly 140 of them were stabilization ponds and 31 of these had been upgraded by chemical pre-precipitation. This paper dealt with the operation experience of five improved ponds in north Finland. Phosphorus removal facilities were added to improve the effluent quality.

Two bottom-lined earth basins were constructed, parallel to each other, and preceding the existing oxidation pond. The detention time was from 4 to 5 hr and the surface loading was 0.3 m/hr. Ferric chloride was fed by a pump from a distribution well into the earth basins. Sludge was withdrawn intermittently from the basins to a sludge lagoon. The optimum dose of ferric chloride was determined in the laboratory first and a value of 100-200 mg/ℓ was observed and used. Sludge was removed by excavation and pumping. Further handling, thickening by settling, flotation and dewatering with belt filters, was performed. Only communities with more than 5000 inhabitants had their own sludge handling facilities. For small communities, a movable belt-filter was jointly owned by 5 or 6 of them.

The results of the operation at the pond in Ii were reported. By pretreating the oxidation pond influent with 230 mg/ℓ ferric chloride, the BOD removal efficiency increased from 53 percent to 84 percent and the total phosphorus removal increased from 11 percent to 73 percent.

During periods of ice cover, the removal of BOD was about 10 percent lower than in the summer. Ice cover and low temperature had no effect on phosphorus removal. Due to impurities contained in ferric chloride, however, iron, manganese and potassium were introduced into the oxidation pond effluent.

The pre-precipitation treatment increased operational costs and produced a considerable amount of sludge, at between 5 and 12 ℓ/day-capita. The per capita construction costs of the improved ponds were between 20 and 30 U.S. dollars.

The main conclusions were 1) pre-precipitation in combination with existing ponds was successful in the operation of stabilization ponds, especially in the northern countries and in treating highly fluctuating wastewater; 2) removal of chemical sludge from the pond was necessary;

3) all ponds should be cleaned from bottom sediments in connection with the described improvements; and 4) the problem of sludge treatment has not yet been solved.

B. Prepared Discussion

B.1 Paper No. 60

Hart (South Africa) commented on the practical operations of the pilot plant. He felt that the effluent from the clarifier still carried much suspended solids (33 to 70 mg/ℓ) and that the clarifier might not be operated under the optimum hydraulic conditions as stated in the paper. He cited the studies done in Pretoria, South Africa. There the addition of 0.5 mg/ℓ anionic polymer and 2.5 mg/ℓ $FeCl_3$ to a wastewater containing 18 mg/ℓ magnesium and pH of 11.2 (with lime) was able to reduce the turbidity of the clarifier to 2 JTU (or 10 mg/ℓ suspended solids) at the same overflow rate (2 $m^3/m^2/hr$) the authors used. The other case he referred to was the Orange County project. The addition of 1 mg/ℓ of anionic polymer to the wastewater originally containing 25 mg/ℓ of magnesium was able to achieve a 2 JTU clarifier effluent. He quoted another work by Irwin and Harbotal (presented at the IAWPR Conference on Advanced Treatment and Reclamation of Wastewater at Johannesburg in 1977) that by adding only Mg(II) at 15-20 mg/ℓ to the effluent of an oxidation pond, the clarify of the overflow did not improve. A significant improvement was obtained with 30 mg/ℓ Mg(II). The addition of polymer (0.5 mg/ℓ) together with 35 mg/ℓ Mg(II) also improved greatly the clarity of the effluent. He questioned the use of 40 to 50 mg/ℓ Mg(II) as it might not be necessary if the polymer was also used. He suggested that further observation to correlate between the Mg(II) dose, effluent clarity and trace metal removal might be beneficial.

Hart elaborated that 1) the average reduction for all metals, except iron in the tertiary pond, was only 20 percent, 2) the suspended solids concentration in the pond was high, and 3) the mechanism of heavy metal removal in the tertiary pond was due to adsorption of heavy metals onto the suspended solids and not to a pH reduction as a result of CO_2 uptake from the air (recarbonation).

B.2 Paper No. 63

Parker (Australia) raised several questions with respect to the selection of the most effective process.

1. Did preliminary removal of phosphorus reduce soluble phosphorus level in the pond below the optimum level permitted for the multiplication of algae in the succeeding ponds?

2. Did fluctuations in pH, normally experienced both diurnally and over long periods, interfere with phosphorus precipitation by alum as suggested by Edworthy *et al.* (Paper No. 38)? This would be relevant to the mode 3 operation.

3. Would flocculation and sedimentation of algal cells, as expected in mode 2, adversely affect biological removal of BOD? Light penetration is usually accepted as being effective with regard to photosynthesis to a depth of about 20 to 30 cm. The ponds were almost 1 m deep.

4. Could pond layout improve the retention and performance of mode 2 operation? Multiple ponds would appear to be a useful method of confining sludge to one pond at a time, and may well facilitate its ultimate collection and removal. The results from the field observation at the Nordseter installation, three ponds in series, did indicate a better effluent than the other two installations, although it was realized that the Nordseter system had a longer detention time and higher aluminum to phosphorus (Al/P) ratio.

5. With regard to sludge accumulation, it was obvious that mode 2 would yield the largest volume of sludge. Did the authors have any practical experience of sludge handling and disposal with this particular system? Although it was stated that the pond was drained and dried, alum sludges and even common sludge without alum dosage would be very slow to dewater and dry. Therefore, it might be advisable to use multiple ponds, with the initial pond discarded at the end of its operation and an additional pond added to the end of the system layout.

6. Was there any information on pH conditions and the nature and number of algal cells for various field installations?

B.3 Paper No. 66

Rantala (Finland) commented that in cold climates, biological reactions occur slowly and the oxidation ponds are covered with ice during the winter time. Significant amounts of phosphorus would be released from the sludge sediment. With chemical precipitation the effluent quality could be improved. However, he was not certain if the phosphorus would be released from the chemically precipitated sludge after some years. If it did, then the overall effectiveness of the improved ponds would be affected. It would be costly and difficult to handle sludge produced. If the improvement was done correctly, the sludge from the bottom of the oxidation pond should be removed before the precipitant was added. This would be a very difficult and expensive task to undertake. He also noted that the precipitant dose was high in these studies and the reason could be improper mixing.

This method had its advantages and disadvantages. He agreed that it was a suitable method, even in the cold climates, to upgrade an existing pond, but he thought it might be better to build conventional biological/chemical treatment plants in order to achieve better BOD and phosphorus removal. Furthermore, the cost of this improved pond process was rather high. He suggested a need to conduct more research on the sludge handling problem and if at all possible to reduce the costs of the process.

C. Floor Discussions

C.1 Paper No. 60

Huang (USA) expressed doubt about the mechanism of heavy metal removal reported by the authors. He thought that precipitation onto metal hydroxides was not a probable removal mechanism. At pH 11.5, most metal hydroxides, except perhaps $Mg(OH)_2$, are very soluble and $Mg(OH)_2(s)$ may not be a good adsorbent for heavy metals. He further questioned the possibility of forming complexes between Cu, Pb, and organic substances, which render the residual concentrations of Cu and Pb unpredictable from solubility products. He did not consider hydroxide precipitation an effective method for heavy metal removal if one includes the ultimate disposal of sludge produced in the whole treatment scheme.

Vrale (Norway) first questioned the necessity of high magnesium and lime doses of this process. He then raised a series of questions: What was the cost of magnesium chloride and how had it been administered? Did you consider any alternative magnesium source such as sea water? Could the variations in the results obtained be due to variations in the magnesium chloride dosing? High chemical dose produces large amounts of excess sludge. Had this been evaluated and what was done with the sludge produced at the plant today?

Author's Reply - Idelovitch replied that they did conduct laboratory experiments to establish the optimum magnesium dosing and pH value used in the pilot plant studies. He testified that the administration of magnesium dose was governed by two factors: 1) the availability of magnesium in the waters, and 2) the problem of algae removal in the oxidation pond. They found a total magnesium concentration of 40 mg/ℓ to be very important. Whenever the total magnesium concentration was less than 40 mg/ℓ, magnesium must be supplemented. The presence of algae in the oxidation pond complicated the administration of lime and magnesium. A study done by Watts and Hoffman in Israel a few years ago indicated that magnesium addition depends not only on the concentration of algae but also on the species of algae. They also found that the magnesium hydroxide particles have a negative electrical charge. This explained why the suspended solids was high in the clarifier effluent since the precipitates did not settle too well.

Idelovitch thought that probably both adsorption onto suspended particles and pH reduction play equally important roles in the additional amount of heavy metal removed in the tertiary pond. The authors did not observe any correlation between suspended solids and heavy metal removal.

Idelovitch did not think that metal hydroxides would be resolubilized in the tertiary ponds since the pH value was gradually adjusted in a series of chambers in the tertiary pond. He insisted that magnesium hydroxide was not such a bad adsorbent. He agreed that it might not be effective in adsorbing some metals but is very good for boron, organic matter and viruses.

The authors are in the process of recovering the magnesium hydroxide from the sludge and more work on sludge disposal will be reported in the near future.

C.2 Paper No. 63

Cille (South Africa) agreed that there were many disadvantages of eutrophication, such as reducing the recreation value, depletion of DO, possibility of toxic algae, and increased cost of water treatment, but he suggested that one should weigh these disadvantages against the cost of phosphorus removal for the purpose of economical justification. He compared the cost of this process with that of a conventional chemical precipitation unit. The cost of this process was 20 to 30 percent more. This was partly attributed to the scarcity of land in Norway.

Idelovitch (Israel) commented that temperature might be an important factor for the operation of an oxidation pond and asked for the climate conditions under which the Norwegian oxidation ponds were operated.

Author's Reply - Balmer answered that the temperature could be up to 21°C during the summer and the ponds were ice covered for about 4 months during the winter when the water temperature was close to 0°C. In responding to the comments raised by the designated discusser, Balmer replied with the following:

1. There was no complete answer to the question of effect of phosphorus removal on the algal population in the succeeding ponds. However, algal activity was observed throughout the whole system.

2. They have noticed considerable pH variations during the day but did not manage to monitor its effect on phosphorus removal.

3. Flocculation of algae did affect the DO level in the ponds. An occasional overdose of alum did flocculate algae cells and then an immediate drop of DO was noted.

4. Their practical experience with layout of ponds with respect to the mode 2 operation was limited. The use of multiple ponds certainly was advantageous.

5. With regard to sludge handling, the only practical experience was limited to the Nordseter installation. The pond was drained twice a year and dried for one month. The sludge was removed with bulldozer equipment. They mixed the pond sludge with primary sludge and experienced a good dewatering operation.

C.3 Paper No. 66

Balmer (Norway) noticed that both the speaker and the official discusser emphasized the importance of sludge removal from the ponds. He commented that the Norwegians have never experienced any problems with having sludge in the ponds except in single cell ponds.

Puolanne explained that the Finish did not intend to add sophisticated sludge dewatering facilities to a simple treatment system, i.e., lagooning and ponding. The Finnish National Board of Water Treatment, therefore, had a goal to investigate simple and natural methods and their modifications for sludge disposal which included improved drying beds by using peat as filtering media, composting, and sludge frosting. The preliminary results were promising.

He did not feel a comparison in the cost of the improved pond with an in-pond precipitation system would be proper. A much more reasonable comparison could be made between the improved pond and the old pond which generally would lead to two alternatives: to build a new pond with in-pond precipitation or to improve the old pond. He agreed, though, that it was true that sludge removal from the old pond would increase its overall cost.

D. Other Observations and Comments

The two-stage high lime-magnesium process has demonstrated its effectiveness in reducing the levels of heavy metals in secondary effluent. In the case of Israel, the operation was significantly governed by the attempt to remove the algal mass. More thorough evaluation of the process is deemed essential in order to apply this process to other systems. Specifically, the high lime-magnesium process might not be the most effective method for heavy metal removal.

Phosphorus removal by chemical precipitation appears to gain popularity and effectiveness in eutrophication control. A more systematic investigation of the three modes of precipitation operation is needed. The Norwegian studies did not provide the most feasible combination of biological and chemical precipitation processes for tertiary wastewater treatment.

IV. CRITIQUE OF SESSION

To claim that the use of high lime-magnesium treatment followed by a series of tertiary polishing ponds is the "most effective" method for heavy metal removal is perhaps overly simplistic. Even the author/speaker admitted that the main concern, besides heavy metals, is the sizable amount of algal mass floating around in the tertiary polishing pond and that high pH and magnesium dose can result in a satisfactorily clear polishing pond effluent. And yet, as pointed out by the official discusser, the turbidity of the tertiary effluent is still high. Furthermore, in a highly heterogeneous solution such as the secondary effluent, one does not expect to have equilibrium precipitation of any kind. A mechanism involving the adsorption of heavy metal species onto suspended solids such as MnO_2 and Fe_2O_3 precipitated in situ is probably more plausible. All these arguments suggest a need to thoroughly investigate the mechanism of heavy metal removal.

It is interesting to learn that the mode of alum addition to domestic wastewater has little effect on the overall treatment efficiency in terms of BOD and P removal as reported by the authors (Paper No. 63). Obviously, none of the three systems were operated under optimum and comparable conditions such as alum dose, pH, detention time, to name a few of the important variables. Therefore, the results cannot be viewed as conclusive relating to the mode of alum addition.

Paper No. 66 is similar to mode 1 of Paper No. 63, except that $FeCl_3$ instead of alum is used as the precipitant. The rationale for pre-precipitating phosphorus from raw wastewater is not very convincing. A better degree of P and BOD removal can probably be attained by post-precipitation with the same facilities but with a different layout.

Chemical precipitation may be the most straightforward technique for the removal of soluble chemical constituents. The most serious setback with this method is the significant amount of chemical sludge produced. Many questions of sludge handling and disposal were raised during this entire session. None of the authors gave any suggestions as to how this problem could be solved at a reasonable cost or any indication of how this could be approached at least on a small-scale basis.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

Heavy metal and phosphorus-related pollution problems are common in the United States and many other countries. Although the technical information presented in this session is not totally new to American researchers in the pollution control field, the practical aspects of heavy metal removal by high lime-magnesium and polishing pond processes in the mid-East Asia region and of phosphorus removal by alum and ferric chloride precipitation in cooperation with oxidation ponds of cold climate regions may lend useful reference information on the tertiary treatment of wastewater in some specific U.S. geographical areas.

Most authors are not fully aware of the limitations and constraints of the chemical precipitation process for the removal of soluble chemical constituents. One important aspect of chemical precipitation is the production of chemical sludge. U.S. researchers in the pollution field might emphasize more chemical sludge research, e.g., sludge settleability, thickenability, dewaterability and recoverability of useful chemicals.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: B
Time: 2:00 to 4:15 pm

B. Theme of Session: Lake Water Quality Relative to Nutrient Sources and Control

II. REVIEWER

A. Name: Lawrence B. Polkowski

B. Position and Affiliation: Professor of Civil and Environmental Engineering
The University of Wisconsin - Madison
Madison, WI

III. REVIEW OF SESSION

A. Formal Papers

A.1 Paper No. 61: "Effect of Nitrification in Orta Lake," by M. Gerletti, A. Provini (Italy)

Lake Orta (Northern Italy) containing 1.3 x 10^9 m^3 of water has been subjected to wastewater discharges for the last 50 years from a rayon factory utilizing a cuproammonia process. The lake has a maximum depth of 143 m and a mean depth of 71 m with a renewal time of 8.1 yr. The industrial discharge is located at the opposite end from the lake outlet, thereby affecting the water quality of the entire lake. Although in-plant pretreatment measures have reduced the copper discharge to the lake since 1956-1958, the ammonia discharges have steadily increased with production and factory expansion. The discharge of the copper and ammonia in earlier periods resulted in severe alteration of the biota with almost complete destruction of the pelagic and benthic biocoenoses followed after a period of time by recolonization of a few phytoplankton and zooplankton species. In any event, the biological processes were strongly affected by the uncommon hydrochemistry of the lake with some of the most interesting features connected to the nitrification processes.

The authors reported on chemical concentrations in Lake Orta over the 50-yr period from 1925 to 1975 using early data reported by others and 1975 data obtained by intensive sampling. Sampling was done in the three sub-basins within the lake at predetermined depths over a 7- to 8-month period representative of winter and warm weather conditions. A significant increase in ammonia and nitrate nitrogen, sulfate, chloride, sodium and specific conductivity occurred from about 1960 to the present. The lack of interim data between 1925 and the early 1960's precluded useful comment for this period although some increases in the above parameters were evident. The mean ionic composition in meq/ℓ for the chemical analyses for the period 1960 to 1975 showed almost a complete balance between the anionic and cationic species measured. The changes in the Ca and Mg concentrations that occurred were attributed to the different analytical techniques used, i.e., titrimetric for earlier data and flame photometry for the 1975 data.

One of the more interesting aspects of the lake hydrochemistry was the pH variation of the water wherein it was noted that at low values of pH, about 4.0, during periods of temperature stratification (warm weather), the nitrate nitrogen concentration was higher than the ammonia nitrogen concentration, while at higher pH, near neutral, the reverse was true. The authors determined the relationship between pH and the difference between the ammonia nitrogen and the nitrate nitrogen concentration. The plotted data resulted in a curve with reverse inflections in the pH range of 6.5 to 8.5 which could not be completely accounted for by the two chemical species. It was noted that calcium and magnesium alkalinity was not present to give any relevant buffering action; in fact, the original natural alkalinity would have only ranged from 0.15 to 0.25 meq/ℓ due to the granitic nature of the drainage basin. This original alkalinity would have been neutralized by the acidity resulting from the oxidation of no more than 1 to 2 mg/ℓ ammonia nitrogen; thus the lake has been acidic for about the last 30 years.

It was apparent that the ammonia minus nitrate versus pH curve obtained from lake values was the result of more than the two species; consequently, theoretical pH values were calculated for mixtures of ammonium hydroxide and nitric acid, 0.78 millinormal each, and experimental pH measurements were made of the mixtures in carbon dioxide free water. This resulted in a similar curve to the theoretical one but both curves differed from the actual ammonia minus nitrate versus pH curve of the lake waters. The difference was attributed to the presence of carbon dioxide in the lake waters. Measurements of pH for mixtures of nitric acid and ammonium carbonate and the mixture of nitric acid and ammonium bicarbonate resulted in a curve similar to but somewhat displaced from the curve resulting from lake measurements. It was apparent that the pH fluctuations in the lake were influenced by the excess of one of the predominant forms, i.e., ammonia or nitrate nitrogen, likely in combination with carbon dioxide or carbonate species.

The historical data showed that the increase in nitrate nitrogen concentration in the lake in the last 10 years has slowed to what may be a steady state in the most recent years. The calculated nitrification rate in the hypolimnion based on mass balances over a period of 7-8 months of thermal stratification resulted in the low values of 2.2 to 4 μg/ℓ-day of ammonia nitrogen converted to other forms. The low rates of conversion were attributed to low pH, low temperature and/or the presence of inhibiting substances.

The authors conducted some laboratory incubation studies in an attempt to elucidate some of the causes for low nitrification. Lake samples from the central basin were stored in lots of twenty to twenty five

250 mℓ glass stoppered bottles in the dark under controlled temperature conditions. At various intervals, two bottles from each lot were analyzed for inorganic nitrogen forms, dissolved oxygen and pH. For samples obtained at the 100 m depth, incubated at 5°C and having a pH of 3.9, no changes in ammonia or nitrate concentrations were found in 140 days. However, the onset of nitrification was evident after 80 days by the appearance of a transitory peak of nitrite. Surface samples taken in July with a pH of 6.7 and incubated at 25°C, had a drop of pH to 4.6 with the oxidation of 1 mg/ℓ ammonium nitrogen to nitrate. In other tests, when an inoculum of nitrifying bacteria was introduced to lake samples with pH adjusted to 8.0 to 9.0, the nitrification proceeded until a low pH of about 4.0 was obtained or when the oxygen levels were limited. The results of the tests indicated the presence of low numbers of nitrifiers at low pH and that nitrification proceeds very slowly at low temperatures. The authors also concluded that lake nitrification inhibiting substances were absent.

The authors indicated that some denitrification occurs in the hypolimnion based on inorganic nitrogen mass balances; however, they were unable to demonstrate this experimentally.

A.3 Paper No. 64: "Restoration of Lake Nakskov Indrefjord, Denmark, using Algal Ponds to Remove Nutrients from Inflowing River Water," by N. Nyholm, P. E. Sørensen, K. Olrik, S. D. Pedersen (Denmark)

The study was directed to methods of removing nutrients from surface waters containing pollution from nonpoint sources to restore freshwater Lake Nakskov Indrefjord. The eutrophication of the lake during the summer months when the lake retention time is about 30 days is primarily related to the high content of nutrients in the incoming surface waters from the Rivers Halsted Å and Ryde Å. During the winter months the retention time is only 2-3 days in the lake, thereby negating the adverse effects of nutrient input. The investigation reported in this paper was directed to the treatment of river water from Halsted Å by the use of algal ponds, one 0.5 m and the other 1.0 m in depth, each with a surface area of 150 m^2 and also in conjunction with the use of two physical-chemical pilot plants, one capable of flocculation-flotation while the other employed flocculation, sedimentation and filtration for the separation of algae and phosphorus. Also, direct chemical precipitation of the river water was accomplished for comparison.

The study was conducted over the period May 1 to October 1, 1976, with river water pumped through the ponds on a continuous flow basis at rates giving nominal detention times of 21 days, for the period May 1 to June 18, and 8 days for the remainder of the study. The shallower pond was stocked with 325 small crucian carps, 124 on June 2, and 201 on June 16, to avoid zooplankton blooms. Measurements of phytoplankton primary production by carbon 14 and by chlorophyll-a, solar insolation and light attenuation, as well as chemical parameters of DO, pH, turbidity, conductivity, total-P, ortho-P, total-N, nitrate, nitrite, ammonia, alkalinity and suspended solids were made routinely over the test period.

Both ponds experienced dense populations of zooplankton early in the investigation; however, in the shallow pond with the stocking of carp in June, high phytoplankton populations, mainly green and blue-green algae, resulted thereafter. The phytoplankton in the deep pond and in the river remained few in number and in species. Attendant with the phytoplankton populations, reduction in inorganic nitrogen occurred. Both ponds reduced the phosphorus level.

In the algae separation studies, a pilot plant involving chemical flocculation and settling, followed by filtration was operated at a flow rate of 480 ℓ/hr with respective flocculation and settling detention times of 39 and 66 min. The filter, consisting of 3 media (30 cm depth of each of 5 mm plast granules over 2 mm anthracite over 1 mm sand) was operated at a filter loading of 5.8 m/hr. The flotation treatment system had a 400 ℓ paddle flocculator and an 80 ℓ flotation unit with detention times of about 1 hr and 8 min (including recycle), respectively, for a flow of 390 ℓ/hr. The recycle was pressurized to 5 atm and alum was used as the coagulant.

The results indicated both pilot systems capable of high phosphorus reductions of pond effluents and river water to concentrations of less than 0.1 mg/ℓ with the use of alum as the sole coagulant. However, alum requirements for the pond effluent with about 60 mg/ℓ suspended solids were 200 mg/ℓ, whereas the river water with suspended solids of 20 mg/ℓ required an alum dosage of 125-140 mg/ℓ. The principal advantage of treating pond effluent versus river water directly was in the reduction of the inorganic dissolved nitrogen; whereas no reduction occurred in treating the river water, almost 100 percent removal was effected by the algal pond and alum treatment.

Both methods of separation, whether flotation or sedimentation-filtration, provided equal removal efficiencies. However, short filter cycles were obtained when treating algal pond effluents as compared to river water.

The float obtained was about 1.5 to 2.0 percent solids and the authors concluded that this method was the most promising.

A model, consisting of deterministic differential equations, provides sizing of the algal pond. The model simulation indicated an area of 4 ha and a retention time of 2.3 days for a constant non-fluctuating water flow which cannot be realized in practice. Although the model simulations predict a marked reduction in primary production and improved transparency in the L. Nakskov Indrefjord with no significant difference between the two treatment alternatives, the algal pond arrangement is recommended and is considered to serve as a "safety factor" particularly in reference to the dissolved inorganic nitrogen. This conclusion was based on the stoichiometric deficiency of nitrogen to phosphorus in the stream water and the ability of the algal ponds to remove dissolved inorganic nitrogen.

The full-scale restoration project included pipelines, pumps, pond, flotation plant, sludge dewatering at the municipal sewage treatment plant and associated structures and would have a capital cost of \$1.08 million and an annual operating cost exclusive of amortization of about \$90,000; this represents a sizeable amount to the communities in the area. Another suggested alternative would be to collect the water from the two streams and bypass the water around the lake during the summer months. This would result in a drop in the water surface of 20 cm of an already shallow body of water (0.9 to 1.0 m) which would diminish the surface area and likely promote the growth of macrophytes.

A.3 Paper No. 67: "The Significance of Sewage Effluent for the Hydraulic and Nutrient Loads on Lakes," by S.-O. Ryding (Sweden)

The objectives of this investigation were to 1) record the municipal waste loading before and after introduction of advanced chemical wastewater treatment or total diversion of the effluent; 2) estimate the percentage of municipal load of nitrogen, phosphorus, and organic matter in relation to the corresponding load from other sources; 3) make nutrient budget calculations; 4) determine phytoplankton relations, algal growth potentials and growth limiting nutrients; 5) determine the time to reach a new level of steady state concentrations in the waste receiving lakes; 6) review the load-biomass relationships; 7) provide information useful for estimating nitrogen removal from sewage effluents.

The extensive sampling program involved some 28 wastewater treatment plants and 25 lakes throughout Sweden. Seven locations were reported in this study with varying sizes of wastewater treatment plants from 2000 to 200,000 population equivalent served and drainage basins having catchment area to lake surface area ratios from 22:1 to over 230:1. The drainage basins reported have areal percentages of forest, agricultural land, densely populated areas, and lake areas ranging from 48 to 88 percent, 7 to 34 percent, 1 to 29 percent, and 0 to 36 percent, respectively, offering a wide variety of land use activity within the drainage basins. The two lakes and associated catchment areas reported in detail in this paper were L. Norra Bergundasjon and L. Nasbysjon having catchment area to lake surface area ratios of 27:1 and 31:1, respectively; percentages of forest, agricultural land, densely populated areas and lake areas were 48/10/29/13 and 88/7/2/3, respectively; wastewater treatment processes for phosphorus removal were post-precipitation with alum for 92,000 population equivalents and simultaneous precipiation with ferrous sulfate for 2000 population equivalents.

Samples from the treatment plants were automatically composited according to flow with analyses for total-P, ortho-P, COD, ammonia, nitrite, nitrate and total nitrogen performed. Samples of lake inlet water were collected weekly and outflow samples were collected when discharge occurred with the same analyses performed as for wastewater treatment plants. The Växjö wastewater treatment plant, which discharges to L. N. Bergundasjon, and the Storvik wastewater treatment plant which discharges to L. Nasbysjon, both experienced high discharge flows in January with secondary peaks in March. The quantity of flow from the treatment works relative to the base flow was significant for L. N. Bergundsajon and exceeded base flows for the dry weather summer months whereas the treated flow volume from Storvik was insignificant in L. Nasbysjon.

Both treatment plants had high mass loadings of total-P, phosphate-P, and COD during the month of January with secondary peaks closely following the discharge flow patterns as one might expect for uniform treatment. However, both treatment systems produced effluent qualities regarding these parameters which were higher in March than the remainder of the year. The poorer treatment performance was ascribed to high flows and perhaps the inability to properly adjust coagulant dosages for maximum efficiency during this period.

Regarding the discharge of organic nitrogen, the results indicated a more even distribution throughout the year; however, for ammonia and nitrate plus nitrite, each plant showed a different pattern wherein the ammonia exceeded the nitrate plus nitrite for Växjö for most of the year; for Storvik the opposite was true during the warm weather periods. Apparently Storvik has a greater ability to nitrify the wastewater than Växjö.

The relative amount of nutrients from the wastewater treatment systems to total discharge of nutrients to the lakes was significant and particularly so during low flow periods corresponding to warm weather and when algal blooms occurred. On an annual average, for the seven drainage systems reported, the wastewater treatment systems contributed 86 percent of the ammonia but only 40 and 43 percent of the nitrate plus nitrite and total nitrogen, respectively, 60 percent of the phosphate phosphorus, 52 percent total phosphorus but only 12 percent of the organic matter reported as COD. As one might expect, the treatment system providing biological treatment without benefit of chemical coagulants had the highest percentages of the total contribution for phosphate phosphorus and total phosphorus as indicated by the contributions to L. Kyskviken of 93 and 86 percent, respectively.

The results of this study have shown that the treatment plants are a significant source of nitrogen during the vegetation period. The diversion of wastewater effluent would likely result in a marked decrease in nitrogen supply which would likely favor the conditions for a bloom of objectionable nitrogen fixing blue-green algae, whereas advanced treatment for phosphorus removal would not drastically change the nitrogen load from the treatment plant. Consequently, steps to improve water quality by nitrogen removal in wastewater treatment plants must be considered carefully with decisions based on the knowledge of annual variation of nutrient loads from wastewater effluent relative to the total load on the lake.

B. Prepared Discussion

B.1 Paper No. 61

Krenkel (USA), along with co-discusser Duwayne of the Tennessee Valley Authority, cited similar experiences with Cherokee Lake, Tennessee, which also received a relatively high nitrogen loading. During the summer stratified period, high nitrogen concentrations in the inflow and very low oxygen concentrations in the outflow were experienced. The temperature varied from 6°C in January with a 6-week detention time, to 9-10°C in April when the lake was filling, with stable stratified temperatures in the summertime of 17°C in the hypolimnion and 27°C in the epilimnion. At least one-half of the oxygen depletion in this lake was attributed to nitrification with time to nitrification noted to be about 5 days at 27°C and 30 days at 6°C. Denitrification was observed as well as production of ammonia from the sediments. One to two mg/ℓ of ammonia was contained in the inflow and up to 2.1 mg/ℓ of ammonia was found in the aerobic portion of the reservoir.

The findings in Lake Orta are as would be expected regarding reported pH, temperature and the concentrations of the various forms of nitrogen. It was apparent that nitrification did take place at the low sampling points (100 and 115 m depth). During the warmer sampling period, the dissolved oxygen was less than 1 mg/ℓ, ammonia and pH decreased, whereas the nitrate concentration increased for these sampling depths. The temperature at the lower depth remained somewhat the same for both the colder and warmer sampling periods. Long detention times in the lake would permit the nitrification process to occur at all times but was not reflected in the winter samples with respect to depth because of the destratified condition. Data of the upper stations indicated that nitrification may be hindered by the discharge from the rayon plant.

There was no information presented regarding the alkalinity or carbon dioxide concentrations. Since CO_2 is needed for cell synthesis by the nitrifier, if the CO_2 is low, the nitrifiers must compete with the algae; in addition, some 6 to 7 mg/ℓ of alkalinity is required per mg of ammonia going to nitrate. Krenkel suggested that nitrification at the two lower or bottom stations may have resulted because of the possible CO_2 produced from organic decomposition. It was suggested that additional CO_2 system data be made available for better interpretation.

The authors neglected several possibly important mechanisms such as nitrogen fixation, denitrification which has been noted to occur in the presence of oxygen such as at the mud-water interface, respiratory reduction, assimilatory reduction, ammonification and the possibility of sorption and leaching of materials from the muds.

The laboratory studies to determine the effects of inhibitors were performed in the dark and, therefore, were not representative of the epilimnion where algal growth apparently occurs. The nitrifying organisms in the dark would not be in competition with the algae for CO_2. Krenkel questioned how the authors prevented the addition of carbon into the system when introducing the nitrifying microorganisms.

The reported effects of temperature disagree with other work. It was noted that the temperatures in the author's bottle tests should have been performed at the temperatures of the reservoir. Since nitrifiers have been observed to acclimate, the results would probably have been different if this acclimation had been allowed to occur.

When the pH was raised in these experiments it was likely that the toxic influence of copper on the nitrifiers would be removed by insolubilization of the copper.

The laboratory studies did not explain the lack of nitrification in the epilimnion which had a good environment for nitrification. It was suggested that an attempt should be made to vary the carbonate-CO_2 system in further studies.

Krenkel solicited comments from the authors concerning environmental problems of the lake in its present condition as to use as a fishery, a drinking water supply, the possibility of other waste discharges, downstream oxygen depletion from releases when mixed with other waters, and carbonaceous BOD and other inputs into the reservoir. It is likely the lake water quality would exceed WHO drinking water standards if all the material were nitrified. Information regarding the type and count of algae present and an indication of how the data were taken for Tables 1 and 2 over the 7- to 8-month period would have been helpful.

B.2 Paper No. 64

Rennerfelt (Sweden) noted that the first step to restoration of lakes is to remove nutrients and pollution at the source which is more applicable to point rather than nonpoint sources as in this instance. The combination of algal ponds and chemical precipitation is capable of removing nitrogen and phosphorus from contributing river surface waters; however, there are some sources of pollution to the lake which would not be controlled. Noting that the area serves as a bird sanctuary, his experience with ducks and wild fowl indicated that they can contribute as much as 1/3 person equivalent for phosphorus, although in this instance the river water has a fairly high phosphorus content already. A more difficult source of nutrients and organic material to control is the decay of vegetation and organic matter such as macrophytes along the shores of the lake. In other experiments it has been shown that the precipitation of phosphorus from the lake waters resulted in resolubilization of phosphorus from the lake bottom as a result of a shift in the equilibrium concentration between the water and bottom deposits. It is apparent that restoration attempts should consider a combination of different methods such as dredging bottom sludges, cutting and removing vegetation, and removing dissolved phosphorus by chemical precipitation of the incoming waters as reported in this instance or attempting to precipitate the phosphorus out of the whole lake.

Although zooplankton populations can be controlled by fish, the question was raised whether the presence of nitrogen fixing blue-green algae may affect the overall performance of the pond system.

The experiments in the ponds were performed with a constant flow rate by uniform pumping when in reality the pond system would have to be operated with fluctuating flows which may upset the ecological balance of the ponds and permit sedimentation of algal with subsequent decay and nutrient release thereby minimizing the effectiveness.

The presence of macrophyte growth in these shallow pond systems could present a handling problem for the large pond under construction.

Lastly, the chemical sludge formed from the precipitation of phosphorus will present sludge handling problems. The alum sludge, about 1 ton of dry solids/day, at 2 percent concentration, will result in about 50 m^3 which must be transported to the sewage treatment plant. The alum sludge is somewhat more difficult to dewater than the wastewater sludge with the likelihood of a dewatered cake moisture content of the mixture to be 12 percent rather than the usual 20-22 percent.

B.3 Paper No. 67

Stegman (South Africa) noted the delicate balance of inputs and outputs in an ecosystem such as lakes with algal blooms possibly representing the most adverse result of eutrophication. Consequently, limiting fertility of the water has been directed to control of nutrient inputs and the author's paper clearly points out the relatively high phosphorus and nitrogen loads from wastewater treatment plants. Algal biostudies in South Africa of 97 impoundments indicated that phosphate was the primary growth limiting nutrient in virtually all oligotrophic impoundments. Of 47 impoundments having algal growth potential values of 25 mg/ℓ, all except two were primarily limited by phosphorus. Some other impoundments receiving more than 10 times the allowable phosphorus loading were found to be limited by nitrogen. If this applies to lakes discussed by Ryding, this might explain why the reduction of 30 to 40 percent of the phosphate load had little effect on some Swedish lakes. Culp (1972) found that a phosphorus concentration of 0.1 mg/ℓ in the effluent of the South Tahoe Wastewater Reclamation Plant reduced algal growth in a reservoir which is made up of water almost entirely from the treatment plant.

Stegman questioned the validity of using nutrient source loading conditions on an annual basis from wastewater treatment effluents. He also requested additional information on 1) the use of COD for organic load rather than TOC; 2) the frequency of flow and parameter measurements used to develop the monthly average plots and what the frequencies should be in general; 3) how important is the size of the catchment area in relation to the background nutrient loads and could this be applied to results of the two lakes reported in detail; 4) the reported densely populated areas if they included industrial areas; 5) the nitrogen-phosphorus ratio that would favor nitrogen fixed by blue-green algae.

C. Floor Discussions

C.1 Paper No. 61

Casapieri (UK) noted that inasmuch as the principal source of wastewater to Lake Orta is from a rayon factory, could not the low pH values experienced be the result of the discharge of sulfuric acid rather than copper-ammonia from the industry?

After having assessed the lake water quality in order to make the lake more environmentally attractive for fishing, for example, or for other predetermined uses, one must have enforcement powers to control discharges. Do these powers exist now in Northern Italy?

Zobrist (Switzerland) noted that the copper content was high for the sampling in the month of March at the same time the pH was low; however, data for copper were not given for the October sampling when the pH was high in the upper lake layer. In that the free copper ion species is toxic to algae, how sensitive are the nitrifying bacteria to total copper content as a function of pH and will acidic rains influence the pH?

Author's Reply - In response to Krenkel's concern over the lack of reporting of CO_2 and alkalinity values, Gerletti noted that the lake does not have calcium and magnesium alkalinity present and that even with higher pH values in the upper layers during the summer months, the titrated alkalinity values were very low. The alkalinity present was the result of the presence of excess ammonia which could be verified by comparing the ammonia nitrogen content against the nitrate nitrogen content shown in the presented curves.

The lack of measurement of CO_2 content was attributed again to no alkalinity conditions whereby titration methods are not suitable. Although some measurements of CO_2 were made by the use of a total carbon apparatus and gas chromatography, the values were suspect as a result of the difficulty in transporting samples from Lake Orta to the laboratory.

The lake contained forms of phytoplankton and zooplankton but no fish. The algal species present seem to be copper adapted but no proof is available to support this comment. In attempts to propagate the natural plankton of the lake under laboratory conditions with control of incubation and temperature, in some instances the algae assimulated nitrate leaving the ammonia. However, the conditions associated with this phenomenon could not be identified. However, the presence of high pH values in the surface layer was attributed to the discharge of effluent with high ammonia and pH 10.0 from the rayon factory with stratification of this flow during the summer months and possibly to the algal assimilation of nitrate in preference to ammonia nitrogen.

Although the total copper content of 50 μg/ℓ has been demonstrated to be toxic to fish under lake conditions, it apparently has no effect on phytoplankton or bacteria at twice the natural copper content of the lake. This observation was verified in nitrification incubation experiments.

The ammonium nitrate content of the water is extremely high which would present a problem if the water were to be used as a drinking water; however, in this instance adequate alpine water supplies in the surrounding area are available.

Attempts were made to estimate a few carbonaceous BODs using values of primary production. Carbon 14 incorporation into the algae was extremely rapid; however, reliable values of primary production were difficult to obtain without the measurement of CO_2.

In answer to Casapieri's questions regarding acidity as it relates to sulfate ion, the discharge from the rayon factory is mainly composed of sodium sulfate, chloride, large amounts of free ammonia and had a pH of 10.0. The balance of anions and cations (not considering ammonia and nitrate nitrogen) in the lake is nearly perfect.

The adoption of a new law on 10 May 1976 (effective 1 June 1979) regarding industrial discharges will limit ammonia nitrogen to 30 mg/ℓ - well below the current concentratin of 1 g/ℓ. Thus, the industry is faced with an additional treatment problem.

In reply to Zobrist's question, he noted that the variation in copper content of the lake during the turn-over and from the first days of spring to the autumn are quite low with the total copper concentration at about 50 μg/ℓ, sufficient to kill all fish regardless of the variation of pH and chemical form of the copper in the surface layer.

Acid rains were not considered to be a significant factor in the water problems of Lake Orta.

C.2 Paper No. 64

Lever (South Africa) questioned the application of the pond to colder climates as opposed to warm climates when algae are used for nitrogen removal. An identified problem in cold climates during the winter months would be the maintenance of a fish population to control the zooplankton for shallow ponds. If the population cannot be maintained, these ponds would have to be restocked during each summer.

Questions were raised as to the solids content of the float on a dry weight basis and the potential uses for the algae. Would the float be used for animal feed and, if so, did the authors determine the protein content or merely leave the float for compost or something similar?

Crouzet (France) noted that shallow lagoons with algae present permit increases in temperature of the water more so than for clear waters. In this instance, was it economically feasible to study the increase in temperature in the artificial basin and the influence of the discharge on the receiving natural basin?

Crouzet noted that watercress was used in the Paris area of France as a plant form for nitrogen removal and could subsequently be used as a fertilizer.

Alternate methods of controlling the discharge or ways of treating the pollutants before going into the environment such as a fjord could be considered. In France, embankments with high grass to intercept the nitrates before discharge to the receiving environment was demonstrated to be effective. When the embankments were removed the nitrates increased, in some cases from levels of 4-5 mg/ℓ to 50 mg/ℓ during actual runoff.

Bjork (Sweden) raised a question whether an efficiency comparison was made between the algal ponds as reported in this paper and the use of macrophytes in wetland areas, noting that the land area requirements for both systems were nearly the same. His observations of these systems in Holland indicated they were efficient during the summer months. He noted that macrophytes were easy to harvest and inexpensive to haul and that machinery for harvesting is made in Denmark.

Author's Reply - The island of Lolland is quite flat with the highest point only 30 m, consequently it is not possible to remove the nutrients from runoff and nonpoint sources; however, minor villages located on these rivers will have chemical precipitation of phosphorus which will result in some improvement. At this point, the pollution resulting from bird population has not been estimated. Investigations in 1974 indicated that the release of phosphorus from bottom sediments was very low. However, in determining how to build the algae ponds, additional information will be needed to determine the release of phosphorus from different points in the Lake Nakskov Indrefjord. The suggested problem of nitrogen fixing algae is not considered a problem in the ponds because of removal of algae from the ponds; however, it is possible that nitrogen can be introduced by nitrogen fixing algae in the Lake Nakskov Indrefjord but it is hoped that this introduction will not be a big problem.

Regarding flow variation to the pond, the project was designed to have the algal pond serve as a flow balancing tank; however, during very heavy storms the system would be somewhat dependent on storage in the rivers before discharge to Lake Nakskov Indrefjord because the river waters must be pumped into Lake Nakskov Indrefjord.

It was noted that macrophyte growth in the pond was heaviest when the phytoplankton content was low and a zooplankton bloom was underway. Upon reestablishing the phytoplankton populations, the weed growth broke up. It is apparent that in practice there are times when it will be necessary to harvest macrophytes.

A municipal treatment plant will receive the algal sludge by sewer with the expectation of increasing the sludge to be handled by 50 percent. During preliminary planning for this investigation, it was thought possible to use the algal sludge for animal fodder as indicated in an experimental study in Israel. However, the sludge produced in these studies has a much lower algal content, about 1/3 algae with the remaining 2/3 being aluminum compounds which were believed to be potentially toxic. The algal pond waters in this study had only 50-60 mg/ℓ of algae as compared to about 200 mg/ℓ in the Israel ponds resulting in a higher concentration of algae in the Israel sludges.

In response to Mr. Lever, the author responded that because of the rather mild winters and seldom thick surface ice in Denmark, a pond 0.9 m deep should be adequate for fish survival during the winter months. In the event restocking is necessary, this would not present a problem.

The temperature in the ponds ranged from a high of 24°C to a low of about 12°C which apparently does not present a problem.

A review of the literature by the authors indicated that macrophyte ponds or wetlands were unable to obtain the low nitrogen concentrations that could be obtained in algal ponds. Therefore, no further investigations of macrophyte ponds were made.

C.3 Paper No. 67

Hallquist (Sweden) felt that the paper indicated that a great change in phosphorus load must occur to provide a significant improvement in water clarity. Also, the importance of load biomass studies was indicated. Hallquist questioned whether the correlation of phosphorus and nitrogen concentration to clarity and the load biomass relation have been studied and, if so, why this information was not presented.

Bjork (Sweden) requested additional information concerning external and internal loading in these lakes after sewage diversion or the introduction of very efficient sewage treatment.

Crouzet (France) summarized some of the thoughts of previous speakers regarding factors associated with eutrophication of rivers. Whereas in deeper lakes with long water renewal times the limiting factor seems to be phosphorus and with rivers, nitrate is the limiting factor, Crouzet asked if the author had any knowledge of the rate of water renewal in the lakes he has studied in that if the renewal is over a period of a few months, the method of approach would not be the same as for water renewal rates of 8-10 months or longer.

Nitrates from surface runoff for the annual dry weather flows accounted for only 3-4 percent of the highest flow as found in his studies in France where the pattern of severe low water levels occurs in the summer with relatively high flows during autumn and spring. Crouzet did not find references about the relative importance of surface runoff during high flow compared to the nutrients which may be contributed from point sources such as municipalities and industries. He noted that the contribution of nutrients from point sources may be minor compared to surface runoff. Studies in France of Lakes Bourget and Leman have shown that about 60 percent of the phosphorus in those lakes came from runoff from areas where fertilizers are applied to the soil. In that the problem is highly complex relative to runoff and hydraulic retention times, additional clarification of the circumstances associated with the reported research would be appreciated.

Duthie (USA) noted that the author remarked there were some 750 treatment plants in operation utilizing chemical or combined chemical-biological treatment. The author was asked if the rather uneven performance of the two wastewater treatment systems selected were typical of the plants in general and whether the results of the advanced treatment are leading in general to better or more even performance in the receiving waters.

Viljoen (South Africa) noted that in some lakes in South Africa during periods of high turbidity, algal growth was extremely low. In reference to periods of vegetation, the question was asked whether the turbidity was caused by algae or was from some other source.

Author's Reply - The sampling frequency of once a week for lake inlet waters and point sources of pollution was selected as being practical for the monitoring of 25 lakes. Flow measurements were also made weekly. In viewing the variation in results for phosphorus, nitrogen and organic nitrogen over a three-year period, different variation patterns emerge for the different parameters. For example, a positive correlation exists between discharge and nitrogen and a negative correlation exists between discharge and phosphorus. The variation pattern for organic matter was more or less evenly distributed for the River Fyrisan. Thus, the sampling was as frequent as possible but, more importantly, was on a continued basis over a sufficient time to plot the different variations that occur in the water. The mass transport of nitrogen and phosphorus in River Fyrisan is primarily regulated by the changes in river discharge, i.e., high mass transport is associated with high discharge regardless of the positive and negative correlations of concentrations to discharge.

The parameter COD was used to represent organic matter rather than TOC because COD is used in all monitoring programs of wastewater treatment plants as directed by the Environmental Protection Board. The easier to perform, more simple COD test is a more practical measure than the TOC test at this time.

Only cursory evaluation of a few lakes has been made relative to phosphorus and nitrogen inputs and the clarity of the lake water. In those few instances where a reduction in nutrient load to the lake has resulted in a positive response, i.e., improved clarity, it was noted that this occurred with reductions in phosphorus load. The status of the reported work is not adequate for making definitive conclusions at this time.

Many of the lakes studied are shallow rather than deep; consequently, it was difficult to predict the time for these lakes to respond to low nutrient input because of internal loading by the nutrients stored in the bottoms and sediments. Phosphorus is released readily during the vegetation period; thus it may require long periods of time for the shallow lakes to respond. The calculation of nutrient mass in the lakes indicated an improvement because of the net outflow of nutrients from the system; however, "steady state" conditions cannot be assumed at this time.

Ryding reported that, with the shallow lakes, nitrogen was the growth limiting nutrient during the vegetation period. Also, lakes have changed from nitrogen to phosphorus limited growth after phosphorus removal was effected in treatment plants. Polluted lakes initially were usually nitrogen limited. The lakes studied have rather short hydraulic retention times of 0.2 yr with no lakes with retention times more than 1 yr.

Ryding indicated that the record since 1972 was somewhat short to assess the manner in which a lake was responding because the varying background loads, wet years and dry years, etc. required investigations over several years to be sure the interpretations will be correct. At present, trends are evident, some indicating improvement, others no change, and even some with poorer water quality. In this sense, the report is inconclusive and will require extensive future interpretive analyses to be made.

The turbidity reported in the paper was related to algal mass rather than the result of other inorganic dispersed materials.

IV. CRITIQUE OF SESSION

The three reports offered a variety of circumstances related to factors influencing lake water quality and the effectiveness of certain control measures. The hydrochemistry of Lake Orta offered a situation where a deep, low alkalinity lake with a long retention time was subjected to high ammonia nitrogen loadings with the attendant nitrification processes, the paper offering a good amount of in situ chemical analyses. The influence of copper on nitrifying organisms was not addressed as completely as one may like to see, particularly regarding the pH effects on the solubility of copper with the resulting inhibition of microorganisms by the soluble copper ion. The laboratory studies did not add much to the interpretive analyses.

In that chemical precipitation of phosphorus from wastewaters and surface runoff by the use of alum has been shown by others, this study demonstrated the effectiveness of the use of algal ponds for the treatment of nonpoint source runoff waters for the reduction of inorganic dissolved nitrogen from waters contributing to lakes that are nitrogen limiting. The application of the pilot results to the design of a full-scale facility was refreshing; however, the paper did not present the model which would have been helpful for future reference. The studies on the lakes in Sweden by Ryding present a wealth of information which unfortunately could not be presented in detail in this paper. Interpretive quantitative analyses were lacking and the justification for and benefits of advanced levels of treatments remains an unanswered issue in many respects.

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The results of the studies presented fail to present a convincing justification for the expenditure of capital and operating monies for advanced wastewater treatment of point sources of pollution when nonpoint sources can contribute significant quantities of nutrients. No assurance that demonstratable improvement in lake water quality will occur with advanced treatment was given. Natural systems such as wetlands are capable of removing nutrients; the determination of phosphorus-limited or nitrogen-limited conditions in the receiving waters is uncertain, and when the receiving lake may undergo a change in biota such as the growth of nitrogen-fixing plankton for a nitrogen altered incoming water. The studies reported and the ensuing discussions demonstrated the need for a definitive assessment of the effects of removing nutrients from lake inflow waters for lakes of similar features and hydrochemistry. The value of the work reported lies in the ability of the researchers to measure the effects, identify similarities and project response of lakes to nutrient removal. It appears that a combined team effort of review and assessment is needed by investigators in this field to provide more useful information and justification as to the need for advanced wastewater treatment.

I. SESSION

A. Day: Thursday, June 15, 1978
Hall: C
Time: 2:00 to 4:15 pm

B. Theme of Session: Halogenated Organics

II. REVIEWER

A. Name: Alan H. Molof

B. Position and Affiliation: Associate Professor
Department of Civil and Environmental Engineering
Polytechnic Institue of New York
Brooklyn, NY

III. REVIEW OF SESSION

A.1 Paper No. 62: "Influence of Oxydising Treatments on the Formation and the Degradation of Haloform Reaction Precursors," by M. Doré, N. Merlet, T. Blanchard, B. Langlais (France)

The paper was concerned with the effect of oxidizing pretreatment on the chlorination of water with reference to halogen production. The oxidizing agents were ozone (O_3) and hydrogen peroxide (H_2O_2)-ultraviolet (UV). Mono- and dihydroxybenzene compounds were used as the organic fraction.

Chlorination of phenol, p. chlorophenol and phenoxyacetic acid do not lead to pronounced quantities of $CHCl_3$ while if an oxidizing pretreatment is imposed, they will yield $CHCl_3$. The amount is a function of the preoxidizing time with the $CHCl_3$ produced passing through a maximum value as preoxidizing time is increased. The dihydroxybenzenes exhibit different behavior; they are $CHCl_3$ precursors themselves and the quantity of $CHCl_3$ formed is decreased as the degree of preoxidation is increased. The chlorination conditions used in this study were close to the optimum for $CHCl_3$ formation and, therefore, the results represent a potential rather than an actual $CHCl_3$ level which would be reached in drinking water treatment.

An oxidizing pretreatment will have a two-fold effect. The $CHCl_3$ precursors, dihydroxybenzenes, will be oxidized to non-precursors but monophenols will be converted to dihydroxybenzenes, $CHCl_3$ precursors, whereupon further oxidation will reduce the amount of precursor.

B.1 Prepared Discussion

Hoigne (Switzerland) commented that although the work is good, it does not mean that in real waters the same problems will be experienced.

This is because real water systems will contain a complex mixture of organics, all of which will undergo simultaneous oxidation at differing rates in an oxidation pretreatment. He contended that the net effect of this will be an overall decrease in trihalomethane precursors as preoxidation is applied - there would not, therefore, be a point of maximum precursor concentration as described in the paper except in synthetic, single organic component waters.

The discussion showed that comparison cannot be made of the relative action of O_3 and H_2O_2-UV. With O_3, the phenol is converted to dihyroxyphenol and then rapidly converted to non-halomethane precursors. The H_2O_2-UV, however, converts the phenol to di- and polyhydroxybenzenes. Only in the final step will the material be converted to non-halomethane precursors. Another difference is that ketones are relatively stable to O_3 but not to H_2O_2-UV.

C.1 Floor Discussions

Young (UK) questioned the lack of information on brominated compounds. The discusser working in this area at Imperial College has found large variations with temperature, pH, concentration of reactants, and questioned whether the author had considered such variations.

Dryssen (Sweden) added a reference, Environmental Science and Technology, 11, 478 (1977). He distributed a data sheet listing the chloroform and bromoform levels at various spots in a water treatment plant. These were:

Treatment	$CHCl_3$ μg/ℓ	$CHBrCl_2$ μg/ℓ
--	0.14	--
First chlorination	3.5	0.5
Reservoir	1.1	0.1
Second chlorination	8.9	2.1
Alkalinization	8.3	0.6
Flocculation	4.5	0.6
Activated carbon	4.5	0.7
Third chlorination	7.7	2.9

He asked if the author could explain these data.

Rapson (Canada) asked if there were any field data to support the lab data. He is working on the exclusive use of ClO_2 since he feels this is the best solution. They have developed an automated method to produce ClO_2 at 1/4 of the present cost.

Dean (Denmark) related experiences at EPA (Cincinnati) which showed that O_3 treatment gave temporary high concentrations of chloroform similar to those shown by the author. His concern is more with bromoforms than chloroforms. He mentioned the use of O_3 also increased BOD and in Norway the BOD produced sufficient slime to clog pipes. He concluded that too little O_3 causes all types of problems.

Author's Reply - The study was limited to $CHCl_3$ production using synthetic waters and thus no bromide was present. He agreed that the reaction speed was dependent on the amount of O_3 added. No residual ozone was present. He used a time scale instead of a scale related to O_3 added as he wanted to compare mono- and dihydroxy compounds. A 3:1 ratio of ozone:phenol yields a maximum production of $CHCl_3$ and corresponds to disappearance but not total degradation. Up to a ratio of 6:1, aromatic compounds will be preserved in the environment. In an infinitely diluted solution of drinking water, the reaction order approaches one and in this case an ozone:phenol ratio of 3:1 is still not enough to destroy the original phenol.

The presence of easily oxidized alcohol in surface waters is quite probable. It was pointed out that only the aldehydes, cetals and alcohols do not give explanations in all cases for $CHCl_3$ formation. The results from the test compounds used will not model humic acid results perfectly. However, humic acids do degrade with O_3 to smaller molecules such as polyhydroxybenzene. Water plant data show the importance of the relation of Cl_2 and the precursor. The increase in $CHCl_3$ and monobromodichlorobenzene after the second chlorination shows the importance of the Cl_2:precursor ratio. It is most probable that the oxidation of bromide by chlorine leads to halobromide derivatives. He is working on tertiary treatment and agrees ClO_2 will not lead to $CHCl_3$. The slow reaction experienced by Young can be explained by transformation of chloromethane to bromoacids.

A.2 Paper No. 65: "Chlorinated and Brominated Lipophilic Substances in Spent Bleach Liquors from a Sulfite Pulp Mill," by D. Dyrssen (Sweden)

This paper was based on the work done in Sweden in developing a mixer-settler apparatus for extraction with materials such as hexane. Problems with tastes in drinking water led to sampling of the river with this apparatus. The results from the river sampling showed chlorinated and brominated lipophilic compounds at much greater levels than PCB and DDT which are toxic materials. Their analytical system picked up low volatile lipophilic organic halogens and not compounds such as chloroform. Their search for the source of these compounds from eight possible locations led to a pulp bleaching byproduct of a sulfite pulp mill. The extraction process used was hexane followed by an alkali wash. This procedure does not pick up phenolics from lignin oxidation, substitution and addition reactions but does pick up lipophilic compounds which are considered the most dangerous types, i.e., DDT and PCB. The study concentrated on cyclohexane extractable materials from different chlorination processes. Chlorinated compounds in the effluents studied were about 1 mg/ℓ.

The occurrence of cymenes in bleachery effluents was thought to be due to oxidation of terpenes and alpha pinenes to chloro- and bromocymenes. The bromide ion source is from sea water. The author pointed out that chlorinated terpentine is a biocide called toxaphene.

A correction for two structures in Table 2 involved changing the OH group to the alpha aliphatic position from the aromatic as shown.

B.2 Prepared Discussion

Eisenhauer (Canada) discussed experiences in Canada where nearly 90 percent of bleach plant effluents are from kraft pulp mills while the author's work was based on sulfite pulp. In work cited by the author by Leach and Thakore, about 80 percent of the fish toxicity of caustic extraction effluent was due to the acidic compounds. Five of the compounds isolated from the acidic fraction of bleachery effluents accounted for 50-100 percent of the overall toxicity.

Good agreement was shown between the fish bioassay and toxicity calculations for each toxic compound in the caustic extraction effluent. This makes chemical calculation of toxicity levels a practical possibility. The discusser suggested that the author develop this technique with sulfite pulp effluents.

Leach and co-workers found that chlorine extraction effluents were less toxic than hydroxide extraction effluents. The principal toxic component in the chlorine extraction effluent was a carboxylic acid with a molecular weight of 384 which is still not identified.

C.2 Floor Discussions

Kopp (Germany) asked about the threshold odor number of cymene and calamenene.

Rapson (Canada) asked for the source of the analytical details of the work presented. He also commented that the bleach liquor can be recycled back to the process after removal of sodium chlorite. Such a plant where the bleachery effluent is recycled is now in operation in Canada.

Author's Reply - The author agreed with the discusser that phenolic substances (hydrophilic) are more dominant among the organohalogens and that only a small fraction is due to the lipophilic and persistent compounds. In the neighborhood of the mill effluent, the fish kills will be from toxic materials as pointed out in the discusser's slides. However, the main concern may be due to the lipophilic and persistent compounds which are in the water at levels near that of DDT and PCB.

The use of water treatment processes to get rid of the problem of pulp bleaching effluents is not a good approach. It is better to change the bleaching process such as the use of oxygen or recycle the effluent back to the process.

The analytical details are described in Ref. 12 of the paper.

A.3 Paper No. 68: "The Effect of Process Configuration on the Formation of Volatile Organohalogen Compounds in Reclaimed Water," by O. O. Hart (South Africa)

Four different process configurations were used to study the effect of chlorine (Cl_2), ozone (O_3), and activated carbon on the formation of volatile organic halogens (VOH) on a tertiary treated wastewater. The configurations were oxidant plus two activated carbon columns or activated carbon-oxidant-activated carbon. Chlorine was added in the laboratory after treatment at 1 mg/ℓ free chlorine and held for various time periods up to 1440 min to simulate the distribution system. The six VOH tested were carbon tetrachloride, chloroform, tetrachloroethylene, bromodichloromethane, dibromochloromethane, and bromoform. The two basic questions were which oxidant, Cl_2 or O_3, produces less VOH and what is the effect of partial removal of precursors?

The author stated that more bromo VOH resulted when the precursor was removed. On the other hand, more chloro VOH was formed when the disinfection is ahead of the activated carbon. The yield, defined as moles VOH carbon/mole precursor carbon, showed a slight beneficial effect when the activated carbon preceded the O_3 and where the carbon followed the Cl_2. Comparison of Cl_2 and O_3 showed 3-4 times VOH with O_3 compared to Cl_2. The author stated that O_3 produces more and stronger oxidants than Cl_2 with the main effect in forming more bromo VOH. He concluded that no substantial reduction in VOH production results when precursor removal occurs and much more VOH results with O_3 than with Cl_2.

B.3 Prepared Discussion

Gomella (France) stated that this paper described how VOH production depended on precursors and configurations. However, it only partially covered the problem and perhaps left more new questions than answers. He objected to the author's reference to industrial chemicals being precursors for VOH stating that this contradicts other work which shows the main source is natural organics. There are many consequences of precursors if one uses powerful oxidizing agents. It would be desirable if more literature references were utilized. The study should not have been reduced just to precursors of VOH but one must also know the role played by the individual chlorinated species themselves. The detention time with Cl_2 is less important than the initial precursor level. The use of Cl_2 or OCl is not the only solution. Chloramine or ClO_2 could have also been used.

The discusser asked what are the results sought in this work. Is it bacterial kill with minimum VOH, with best quality water, or with maintenance of a residual in the distribution system? Why should disinfected water have Cl_2 applied at 1 mg/ℓ free Cl_2?

The discusser stated that, from Figs. 2-5, O_3 between two activated carbon filters is satisfactory. However, deterioration is caused when excess Cl_2 is added. The use of activated carbon and O_3 was not questioned by the discusser but the high rate and double use of Cl_2 was. For distribution system protection, different compounds than Cl_2 could be used. Experiments should be conducted on these points. The recommendation of the discusser is O_3, activated carbon, and biological activated carbon.

C.3 Floor Discussions

Hoigne (Switzerland) found it difficult to explain the reason for the results. However, he found good correspondence with other literature. He asked if the O_3 just converts the aromatic ring VOH precursor to a non-VOH precursor while the ketone precursor is not converted. He concluded that from this work and the literature that this type of alkyl compound is a better precursor than aromatic precursors.

Doré (France) was interested in the comparison of processes A (O_3 + activated carbon) and C (Cl_2 + activated carbon). He asked why in A does the trihalomethane (THM) occur somewhat later, i.e., 12 hr. The paper explains it appears rapidly in C and prechlorination gives more precursors than preozonation. However, elsewhere THM formed is four times more with O_3. Even though the final Cl_2 was the same, the initial Cl_2 was not. This is important since the ratio of Cl_2 to precursor influences the THM formation and the kinetics of reaction. He questioned if it was possible to compare A and C on a kinetic basis.

Coin (France) stated that work in Paris is in progress on a plant scale with a river water containing known precursors. By changing the process, the precursor is eliminated by filters and the final O_3 did not produce THM. He stated that he believed the use of breakpoint chlorination in the beginning is not a valid method.

Pomeroy (USA) asked why the term VOH was introduced which isn't consistent with standard terminology?

Hoigne (Switzerland) stated that the problem of VOH could be eliminated by the use of ClO_2. However, other countries have problems in using ClO_2 due to a standard of 0.1 mg/ℓ for chlorite. What is the basis for this value and is it based on sound reasoning?

Coin (France) stated that sodium chlorite has an effect on the user. Therefore, health authorities want to limit chlorite supplied. He concluded that precursors ought to be removed so Cl_2 and O_3 could be used satisfactorily.

Rapson (Canada) remarked that ClO_2 is made from $NaClO_2$ and Cl_2 and results in ClO_2^- if the ratios are not correct. He proposes to make ClO_2 from sodium chlorate and SO_2 and, therefore, there would be no sodium chlorite. However, ClO_2^- is a product of ClO_2 and organic matter. Therefore, it can be present but in very small amounts.

Author's Reply - The experiment was relatively small with limited scope and did not include theoretical studies.

The question of why two disinfectant steps were used has been raised. In a water reclamation plant, there must be insurance of safety barriers for organics, trace metals and bacteria. WHO states two barriers are needed for any contaminant. South Africa feels the need for 4-5 barriers for bacteria and virus. They use breakpoint chlorination in the first stage for complete disinfection.

The previous plant operation involved the use of Cl_2 before two activated carbon columns with a total detention time of 30 min. Because of the question of THM, it was decided to vary the process by inserting the Cl_2 or O_3 between the two carbon columns and determine the resulting effects of having partial precursor removal.

The answer to why one gets more bromo compounds with O_3 is that one carbon column cannot adsorb enough to reduce VOH formation with Cl_2.

Doré (France) showed in his paper that certain compounds like phenol and phenyloxyacetic acid will not lead to formation of THM. But once these are oxidized, they will become THM precursors. That is, perhaps, why O_3 oxidation gives higher THM precursor levels.

The removal of precursors in river water as described by Coin may not be possible in wastewater reclamation. The use of the term, VOH, was only for this paper. They usually use VCO (volatile chlorinated organic).

V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES

The subject of halogenated organics is of great interest because of the recent data possibly linking these compounds with cancer. Their presence in drinking water is now of direct concern to the EPA. The information from these papers, therefore, can be directly applied since wastewaters can directly affect drinking water supplies.

The paper (No. 65) on bleachery effluents is now directly applicable to paper pulp plants which use the sulfite process. It also has application to pulp mills that use the kraft process since the approach presented appears new. The paper (No. 68) on tertiary treatment disinfection provides more information on how to minimize halogenated organics. This work relates directly to water reuse applications. The paper (No. 62) on ozone and hydrogen peroxide-UV disinfection provides comparative data on these compounds. This information can be applied to both water and wastewater.

All the papers introduce areas that need more research. Production of halogenated organics is to be minimized and the type of information presented in these papers is required especially in water reuse applications.

CHAPTER III

OVERVIEW OF PERTINENT CONFERENCE DEVELOPMENTS

In this chapter, pertinent developments at the Conference as reported by individual participants are briefly summarized and categorized. The chapter represents primarily a summary of Chapter II. However, the chapter also contains a summary of other observations made by individual participants regarding international developments of potential interest to EPA which did not emanate from the formal program of the Conference.

Developments at Formal Sessions

This section highlights the individual reports contained in the previous chapter by reviewing the more significant observations and conclusions according to various categories of water pollution research interest. In each case, comments are identified by the paper number or workshop title to which the observations relate. Comments included here may not necessarily be contained in the formal papers but may have developed from discussions at the Conference. Paper numbers and workshop titles are included to facilitate reference to the more extensive analyses of Conference developments included in Chapter II. By referring to the paper or workshop of interest in the Table of Contents and Key to Reviews, the location of the corresponding discussion in Chapter II may be determined.

Biological Wastewater Treatment --

A new apparatus was described (Paper No. 52) which measures the response of a biological system to an imposed waste feed. The rise or fall of oxygen uptake rate shows activation or inhibition of a biological system.

A new instrument for measuring the concentration of activated sludge in a reactor was described (Paper No. 55). It involves measuring the weight deviation between a given volume of mixed liquor and the same volume of interstitial water obtained after removal of the suspended solids. Several months' use of the instrument at two sewage treatment plants has shown good correlation with gravimetric measurements.

Chemical Oxidation --

A model for ozone oxidation was presented (Paper No. 49) which lends considerable insight into the oxidation phenomenon. The effects of pH and various solutes on ozonation reactions were clearly presented, e.g., ways of keeping ozone undissociated to effect better disinfection or a specific organic oxidation were defined.

Another paper (Paper No. 62) described the effect of oxidizing pretreatment on halogen production when the water is subsequently chlorinated. The practical value of the results may be limited, however, because of possible errors in data interpretation pointed out by discussers.

Also with respect to the production of organohalogens, a paper from South Africa (Paper No. 68) described the effect of chlorine, ozone and activated carbon on the formation of halogenated compounds in reclaimed wastewater.

In the discussion of Paper No. 62, Rapson (Canada) stated that "an automated method" to produce ClO_2 at one-fourth the present cost has been developed.

Adsorption --

Appreciable international interest was exhibited in systems for simultaneously accomplishing biological oxidation and adsorption on activated carbon (Paper No. 1). Research is needed to expand the mechanistic understanding of the joint process to permit full development of its utility.

Results of a full-scale installation involving adsorption of nonbiodegradable components of pulp bleaching wastewater on aluminum oxide were reported (Paper No. 7). Effluent from the aluminum oxide adsorption process was treated biologically.

Preliminary results were presented on a technique for removing a toxic heavy metal [Cr(VI)] by carbon adsorption (Paper No. 4). Interpretations differed on the mechanisms involved in chromium adsorption and reduction, and optimal implementation of the possible process requires improved understanding of the mechanisms.

It was reported (Paper No. 42) that there were similarities between the sorptive capacity of activated sludge for organic dyes and the so-called manufactured and expensive sorbents, such as activated carbon. Others indicated that dyes are poorly adsorbed by activated sludge. On the other hand, it was pointed out that the sorption of toxic substances, both inorganic and organic, as well as dyestuffs, should not be overlooked in treating wastewaters containing such material.

Filtration --

Two researchers (Papers No. 10 and 19) reported on the use of a rationally determined "filterability" number for the evaluation of the performance of deep bed filters for the removal of suspended matter from wastewaters. The two numbers were derived independently and, although they are not identical, are remarkably similar. This number was used

(Paper No. 10) with a simple, compact and portable laboratory filter for the evaluation of operational procedures in water or wastewater filtration. There was considerable discussion on the filter's applicability for determining design parameters, the concensus being it was not developed for this purpose. In Switzerland (Paper No. 19) the number was used to pre-optimize the variables in the design of deep bed filters for the removal of suspended solids from the effluents of chemical-biological treatment plants removing phosphorus and organic matter from wastewaters.

Two other researchers (Papers No. 13 and 16) developed models to be used in the design of deep bed filters. Both these researchers, and several discussers, emphasized that particle size and particle size distribution were important parameters in filter design.

Combined Physical-Chemical-Biological Treatment --

Several papers emphasized the importance of examining physical-chemical-biological treatment systems comprehensively rather than as separate parts. Paper No. 54 was a very thorough presentation on this subject and included a number of insights into the performance of various combined systems. It is worth special mention that the Swiss approach to organics analysis is to measure total or dissolved organic carbon in lieu of BOD.

The precipitation of heavy metals by high lime-magnesium treatment was reported (Paper No. 60). Results indicated that heavy metal residual concentrations are all below limits imposed by WHO's 1971 drinking water standards.

High lime-magnesium treatment was reported to be an economical means for upgrading the quality of oxidation pond effluent (Paper No. 9). The technique, being investigated in Israel, is carried out in a reactor-clarifier followed by polishing/recarbonation ponds.

Another paper (Paper No. 66) described the use of chemical precipitation in combination with stabilization ponds in Finland. Substantial improvements in treatment efficiencies were reported.

Nutrient Removal --

It would appear that nutrient removal was the dominant consideration of the Conference. The views of the Conference participants were strongly flavored by their home country situation. Water-rich countries (such as Scandanavia) with eutrophication problems were strong on nutrient removal. Water-poor countries (such as Israel) which had to rely heavily upon water reuse advocated activated carbon tertiary treatment of wastewater regardless of the cost.

Numerous references were made to full-scale plants for N and P removal that are already operating or under construction. There are more prototype installations than there are activated carbon plants, indicating that more countries are committed to N and P removal than to tertiary carbon removal.

There was a general feeling in the session including Papers No. 29, 32, 35 and 38 that the financial burden of chemical costs associated with N and P removal is becoming excessive and significant. This feeling even appeared to be true with the more advanced countries. Thus, there is increased interest in removing N and P by biological means, without the addition of any chemical.

A series of papers (Nos. 29, 32, 35 and 38) covered various system configurations and operating parameters associated with nutrient removal. It was questioned (Paper No. 29) whether advocacy of plug flow reactors for nitrification in the EPA Process Design Manual for Nitrogen Control is appropriate.

There was considerable interest in the interrelation of the various treatment unit operations for nutrient removal. For example, phosphorus removal is dependent on complete nitrification; effluent filtration is critical to removal of phosphate precipitates to achieve low effluent phosphorus; coagulation is critical to effective filtration; adequate aeration capacity is crucial for effective nitrification; equalization is crucial for preventing diurnal ammonium breakthrough; and the method of sludge disposal is crucial to prevent phosphorus from reentering the aquatic ecosystem.

Some fundamental inconsistencies must be resolved in biological systems for the removal of N and P. The environmental conditions required to achieve biological removal of phosphorus are ill defined. The Canadians report low P removals and the South Africans report high P removals.

The process configurations utilized for nitrification-denitrification are quite varied and appear to be subject to considerable "personal" choice. Some advocate one-sludge systems while others advocate two-sludge systems. In view of the common difficulty reported, i.e., nitrification under winter conditions, a reviewer expressed surprise that fixed film systems are not advocated more for nitrification of activated sludge effluents. Suspended growth systems are subject to continual wasting as effluent suspended solids which are not always removed by secondary clarifiers. This makes it difficult to achieve the requisite extended SRT values required for cold weather nitrification.

A submerged filter was reported (Paper No. 2) to be effective in accomplishing biological oxidation of ammonia. While the application (oxidation of ammonia prior to use of a surface water in France as a water supply) may not be appropriate to the United States, the fact that the process was effective at temperatures as low as 6°C is of interest.

There is worldwide interest in the removal of nitrates from wastewaters (Papers No. 12, 15, 18 and 21). This interest is based principally upon public health concerns although eutrophication is a lesser concern. Emphasis is being placed on biological processes because they are most cost effective. Research was concerned with biofilm diffusion (Paper No. 12), kinetics in a submerged rotating biological disk (Paper No. 15), and treatment of high nitrate wastewaters (Papers No. 18 and 21).

Norwegian research (Paper No. 48) has shown that the addition of 2-3 percent seawater to a lime precipitator allows the lime dose to be reduced by about 35 percent while still achieving high efficiency phosphorus removal and substantial removal of organic matter. The seawater serves as a source of magnesium when soft waters are being coagulated.

A Swedish paper (Paper No. 51) summarized operational data from ten physical-chemical-biological treatment plants; however, data are available from the authors from several hundred other plants. The authors compare system performance on the basis of effluent phosphorus concentrations which should provide useful information to designers seeking to achieve various degrees of phosphorus removal. Data available on sludge characteristics may be of particular value.

Methods for combining oxidation pond treatment with alum precipitation were described (Paper No. 63). Treatment efficiencies were described as "promising"; they were on the order of 80 percent for phosphorus as well as BOD, COD, suspended solids and nitrogen.

Sludge Management --

A technique developed at the British Water Research Centre for characterizing the thickenability of sludge using small samples in a laboratory centrifuge was reported (Paper No. 3). The technique is intended to allow determination of the maximum achievable thickened sludge concentration and to provide guidelines for thickener design.

Results of a Canadian study (Paper No. 6) indicated that substitution of polymers and pulped newsprint for the conditioning agents lime and ferric chloride resulted in improved overall economy of sludge dewatering and incineration; but, still, autogeneous combustion could not be achieved. This installation, at Windsor, Ontario, is expected to have a payback period of two years.

Characteristics of a sludge produced by lime treatment of oxidation pond effluent were described (Paper No. 9). Magnesium was added to the reactor clarifier to promote flocculation and later removed from the sludge to improve dewaterability.

Stream and Estuarine Analysis --

A Swiss paper (Paper No. 5) involved development of mathematical models describing the conditions in rivers of various types resulting from differing types of pollutional loads. The approach may have applicability in the United States for differentiating between various sources of pollutants and for determining relationships between various inputs and resulting conditions in the receiving water.

A Hungarian investigator (Paper No. 8) presented a two-dimensional mixing model for use in wide streams where transverse mixing is significant. The reviewer considered that, while the work is of interest for application in the United States, the extensive data base required may restrict its utility.

Information was presented (Paper No. 30) to show that the use of the Thames River estuary model, developed in the late 1950's, has paralleled improvements in the water quality of the estuary.

Canadian investigators (Paper No. 24) studied the fate of methylmercury in a reach of the Ottawa River. It was concluded that most (97 percent) of the mercury resided in the bed sediments, that bed sediment movement had little effect on the downstream movement of mercury, that biomass contains an insignificant portion, and that the primary transport vehicles are the suspended sediments (58 percent) and the water (41 percent). Several discussers questioned the conclusion that bed sediment transport was insignificant.

Pollution of two rivers in series and a downstream reservoir in Hungary by heavy metals and petroleum derivatives was studied (Paper No. 28). Heavy metals accumulated in the bottom silt during low flows and were subsequently resuspended and transported during flood discharges. It was determined that polycyclic aromatic hydrocarbons extracted from the bottom sediments by benzene were bioresistant and, therefore, increased in relative concentration with distance from the polluting source. A consensus from the discussion was that heavy metals should be contained at the source.

Pollution in Seawater --

There was considerable interest in research (Paper No. 11) that developed a model that predicted bacterial survival in seawater. The model may have application to some of the recent health problems experienced with shellfish in Louisiana. Another investigator (Paper No. 14) described a method for determining dispersion coefficients in seawater which should be useful in studies of this nature being conducted at some coastal cities in the USA.

In Denmark (Paper No. 17) a sophisticated hydraulically based, multiparametric model was developed for the determination of phytoplankton growth in coastal waters. Although discussion of the paper revealed deficiencies in the model, it should be a stimulus for future research in the USA.

One reviewer suggested that study of water conditions in the Stockholm Archipelago (Paper No. 20) along with information contained in Paper No. 17, should be helpful in determining the degree of treatent wastewaters should receive in Hawaii.

Significant concentration of hydrocarbons from seawater by bivalves was noted by investigators from Denmark (Paper No. 26). They noted a rapid release of these compounds when the bivalve was placed in fresh water; however, most of the discussion indicated the release would be quite slow.

Groundwater Contamination --

Paper No. 36 concerned the application of treated effluent and sludge in the Chalk formation of the UK. The research indicated that bacteria and viruses can penetrate a distance of over 15 m but less than 100 m; on the other hand, degradation of groundwater quality can extend to a distance of 2 km.

It was pointed out in discussion of Papers No. 33 and 36 that land disposal of wastewater effluent and sludge should be considered as reuse systems rather than disposal systems in areas where groundwater is used for water supply. Disposal sites should be selected with this in mind. It would appear that sites with questionable geologic formations are permitted to be used in the UK. Objections to this practice were expressed.

The application of sludge to sandy soil potentially may lead to the virus contamination of groundwaters (Paper No. 44). The clay content of soil appeared to be important in restricting the movement of viruses. A red sandy soil of Florida was found to be effective in preventing virus contamination of groundwater. The applicability of the research was questioned because of its laboratory nature. The use of a high concentration of virus and the recovery methods used also were questioned.

Indicator Organisms --

With the increasing use of wastewater reclamation, indicator organisms, particularly for viruses, need to be identified. One author (Paper No. 25) reported on the use of bifidobacteria for this purpose. Three major drawbacks to their use remain: 1) test methods are complex, 2) the organisms are sensitive to dissolved oxygen, and 3) they have a low survival rate in the extrainternal environment.

Another investigator (Paper No. 27) presented useful data on the occurrence of pathogenic bacteria (*Salmonella* sp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*) in streams flowing through urban areas. These data are badly needed as most previous studies have dealt only with pathogenic bacteria. The value of the results would have been increased if virus data had been included.

Research workers in South Africa have made a major contribution (Paper No. 23) in demonstrating that the microbiological aspect of wastewater reclamation was controllable and, therefore, was of minor significance as compared to the chemical aspect. However, other researchers (Papers No. 44 and 46) indicate that virus movement and survival in soils and ponds should receive more attention because of the public health aspects of water reuse.

Virus survival in the sediments of holding ponds was reported (Paper No. 46). Inactivation of virus in the upper layer of water occurred because of increased pH resulting from algae growth. Water taken from the lower layer or the sludge deposit would pose a potential health problem if withdrawn for subsequent land disposal. The method used to recover virus from the sludge or sediment was questioned.

Nonpoint Source Pollution --

In monitoring an area consisting of forests, agricultural activity, and a suburban-urban development, it was observed (Paper No. 43) that point sources of runoff to a water course during periods of minimum storms accounted for less than 15 percent of the total nutrient load. On the other hand, drainage from urban land was found to export much more N and P than an equivalent amount of rural land.

There was considerable interest in developing methods for analyzing and describing the nutrient load, both from rainfall and runoff, as it is affected by various parameters. A method (Paper No. 45) using coaxial relationships was described. It appeared to be a useful method in approaching the physical phenomena that are nonlinear and are not normally distributed. However, the individual characteristics of each catchment area must be considered. For example, in discussion it was reported that in Hungary 20 percent of the P and 40 percent of the N comes from precipitation. A corrective measure of this source of nutrients would be to control air pollution.

A paper from the U.S. (No. 50) also contained data on the effects of rainfall on the quality of runoff from four different land-use types. The quality of rainfall *per se* was found to be important with regard to concentrations of nutrients and organics.

Another paper (Paper No. 53) described a procedure for supplementing the data base on quality of storm runoff by studying existing long-term records on influent quality at a sewage treatment plant serving combined systems.

Yet another paper (Paper No. 56) questioned the assumption that the character and intensity of nonpoint pollution may be predicted from knowledge of land use and from generalized pollution loadings for each use. Rather, the authors proposed an alternative approach which included land use and also a variety of other factors.

A novel device, the Teacup Separator, for separating solids from storm and combined flows was also described and evaluated (Paper No. 59).

It would appear that many countries are concerned about the pollutants, including nutrients, from nonpoint sources. It is generally acknowledged that an impact exists, but the extent and magnitude of the impact as compared to point sources are not fully known. Another problem (Paper No. 47) is that it is nearly impossible today to forecast accurately the impact on receiving waters or to evaluate potential solutions, such as land management practices or treatment plants. The information presented described water sampling and collection programs and various techniques for analyzing data. The latter aspect, together with the format used in presenting the results, is important in forecasting the impact of storm water and runoff. It was stressed repeatedly that each catchment area must be considered on an individual basis.

In discussing potential solutions to eutrophication caused by storm water runoff (Papers No. 43 and 45), it was reported that retaining ponds and weed plantations are used in Hungary to remove nutrients. Johannesburg (RSA) uses a 2 km long ditch with vegetation to remove nutrients from the effluent of a wastewater treatment plant. Both of these processes require little energy. It was pointed out, however, that more about the methods should be known, e.g., land requirements, design loading criteria, and actual nutrient removal efficiency.

It was interesting to note from discussion of Papers No. 45 and 47 that the Swedish Environmental Protection Board is divided between whether future wastewater collection systems should use separate or combined sewers. Apparently everyone agrees that stormwater runoff and sewer overflow contribute a significant impact on receiving waters. However, funds are limited to construct and operate stormwater treatment facilities. The major concern regarding storm water runoff is the impact of P on the eutrophication of small lakes and streams.

Industrial Wastes --

Chemical and physical components of the major liquid waste streams from steam-electric power generation were characterized in a paper (Paper No. 58) by TVA engineers.

A Swedish report (Paper No. 65) indicated the presence of both chlorinated and brominated lipophilic substances in the spent bleach liquors from sulfite pulp mills.

Water Pollution Problems in Developing Countries --

The need to emphasize simpler systems of wastewater treatment in developing countries and to get away from the more complicated, sophisticated methods was a major thrust of Workshop II. It was indicated that the World Bank had made this shift in emphasis and, in addition, was giving more attention to rural problems of wastewater treatment. Research on the development of simple wastewater treatment systems and their application, particularly in rural situations, can potentially be significant to the U.S.

In most situations in developing countries, the needs for adequate and safe water supplies are given preferential consideration, particularly with respect to the funds available. The thought was expressed that the development of both water supply and wastewater treatment facilities should proceed simultaneously.

Developments Outside of Formal Sessions

Much of the beneficial exchange of technical information which occurs at professional meetings takes place outside of the formal meeting rooms, and at international conferences the opportunities for effective information transfer by this means are considerable. Participants in the development of this report were asked to submit comments obtained from such interactions with water pollution researchers from other nations. Several of the participants also submitted comments on the value of the international exchanges on water pollution research. These reactions and items of possible interest to EPA which were not a part of the formal Conference program are summarized in this section. The comments are attributed to individual participants and do not necessarily reflect the view of USANC.

Biological Wastewater Treatment --

The need for a worldwide unified system of symbols for biological kinetics was felt to be a significant need. Grau of Czechoslovakia and Harremöes of Denmark are planning efforts towards accomplishing this (Randall).

Nitrification --

At the Stevenage Lab in England, the combined treatment of primary wastewater and a nitrified effluent in a fluidized bed biological reactor is being researched as an economical technique for accomplishing both denitrification and carbonaceous treatment. This method eliminates the need for addition of a carbon source such as methanol and oxygen introduction to the biological treatment process for wastewater treatment (Randall).

A trend towards the utilization of fixed film systems for nitrification was voiced by several, particularly Harremöes and others in Denmark (Randall).

Phosphorus Removal --

Nicholls (South Africa) is involved in the operation of full-scale plants designed to utilize biological removal of phosphorus. Current operation appears to be successful. Additional research into the control of uptake and release in both aerobic and anerobic environments is planned. Considerable research into the factors that control phosphorus transformations during biological treatment is still ongoing at several locations, particularly in Denmark and Norway (Randall).

A chemical treatment process to remove phosphorus and/or suspended solids by the use of an upflow contact sand filter has been developed in Sweden. Chemicals are added to the suction side of a pump and mixed in the pump whereafter small floc forms in the discharge pipe, the stream is introduced at the bottom of a sand filter and the purified water is forced to the surface of the filter for discharge. A special backwash pump that can pump untreated water through the same distribution and filtration system as used to treat water is utilized. This system not only is effective in removing BOD and phosphorus but also pathogens and can be used in lieu of effluent chlorination. It was reported that there are over 20 of these full-scale installations throughout Europe (Kerri).

Physical-Chemical-Biological Treatment --

In developed countries there is a noticeable trend away from energy-intensive sophisticated treatment processes and a return to biological systems for achieving desired objectives. There are still many challenges remaining for research investigators regarding the optimum design of physical-chemical-biological systems. The choice of the appropriate combinations will depend on the specific site conditions, including the chemistry of the wastewater, effluent discharge standards, and ultimate disposal problems. Research in the wastewater treatment area should be focused on the impact of various unit process combinations on overall treatment costs and removal efficiencies. Water pollution control in developing countries will require a different approach. Most individuals emphasized the need for a less capital-intensive technology in developing countries and discussed the need for research on simple, low-maintenance, labor-intensive techniques for solving water pollution problems in developing nations (Kavanaugh).

Sludge --

The Conference provided an opportunity to discuss cooperative research studies elsewhere in the world. For example, the European Economic Community is restarting its EUROCOP-COST '68 program on sludge handling and disposal. Various countries have agreed to undertake research studies in one or more of several topic areas, e.g., processing, characterization/analytical, utilization, and disposal. A registering of projects has been completed and progress reports are planned at a series of meetings. No interface with the U.S. research community has been set up as yet (Conway).

There appears to be much emphasis on the further utilization of municipal sewage sludges. It appears that where this material is contaminated with heavy metals something needs to be done but exactly what is not known. Some feel that the problem should be attacked through the control of industrial discharges and that this will solve the problem. Others disagree, indicating that nonpoint sources are the biggest contributors in this area, and that work is needed on how to control these diffuse discharges. There may be merit in both the approaches, depending upon the particular situation (Goodgame).

Nonpoint Sources --

The extensive attention other countries, notably Switzerland, Germany and Sweden, have been giving to nonpoint pollution characterization and treatment was discerned from sessions and private conversations. Switzerland, in particular, has launched a nonpoint pollution abatement program that includes modification of roof drains, storage and chemical treatment, overland treatment and several other techniques. Investigations in all three countries have determined that a large fraction of the nonpoint pollution originates as air pollution and reaches the ground primarily during precipitation events. A Swedish researcher reported that 25 percent of the nonpoint pollution originates as air pollution whereas a German researcher reported 50 percent. By comparison, studies by this reviewer in the Washington, D.C. area indicate that most land areas are sinks for atmospheric pollutants rather than net sources of runoff pollution. The differences can apparently be attributed to air quality in the areas studied. Several nonpoint characterization studies are ongoing in England. Facilities at the Technical University of Denmark, located on the outskirts of Copenhagen, is a model of incorporating nonpoint pollution abatement design. All parking lots and open areas are designed to maximize infiltration by use of pervious pavement, lattice pavement and vegetation (Randall).

Several unique methods for treating nonpoint pollution have been investigated in Sweden. One scheme utilizes plastic partitions inside a lake to catch the runoff during high flow, store it, and permit recirculation through a chemical treatment plant after the runoff event (Randall).

Discussions with researchers revealed the general belief that future nonpoint control techniques should involve architectural, landscape and land use design with emphasis on infiltration rather than structures and treatment processes (Randall).

The nonpoint pollution researchers consistently reported four metals in greatest abundance (copper, lead, zinc and chromium) but seemed at a loss to explain their abundance. This was particularly true for zinc, and some rather farfetched explanations were given. This reviewer has found the same four metals but believes their presence is easily explained in terms of their presence in automotive products, fuels and fertilizers. Cadmium, however, was considered to be the metal of greatest concern (Randall).

Industrial Wastes --

The consensus of discussions of methods of recovery of spent sulfuric acid pickle liquor was that there is no good process for this recovery. There are some severe problems along the French coast due to discharges of spent sulfuric acid. One company has worked on submerged combustion for several years and thought they had a viable process, but it did not work out (Goodgame).

Relationship between Water and Wastewater Treatment --

Bertil Hawerman's (IAWPR President) opening speech for the Conference called for a better working relationship between those concerned with water supply and water pollution. Throughout the Conference this reviewer was struck by the importance and direct relationships between the papers presented at the Ninth International Conference on Water Pollution Research and the area of water supply. While there were several examples one might suggest, Paper No. 23, "Microbiological Quality Indicators for Routine Monitoring of Wastewater Reclamation Systems," Paper No. 46, "Survival of Poliovirus in Model Wastewater Holding Ponds," Paper No. 62, "Influence of Oxidizing Treatments on the Formation and Degradation of Haloform Reaction Precursors," or finally Paper No. 68, "The Effect of Process Configuration on the Formation of Volatile Organohalogen Compounds in Reclaimed Water," are just as important for those interested in treating drinking water as those concerned with the treatment of wastewater. This feeling was not unique and Shuval (Israel) expressed it more directly when he stated that a closer relationship should be or must be developed between those interested in wastewater and drinking water treatment (Hanes).

Several participants commented on the need for directing the water-related research efforts to safe drinking water problems in the world and the provision of basic sanitary handling of waste residues for the developing countries. Advanced wastewater treatment affected a relatively small fraction of the world population whereas improvement of basic sanitation of water supplies represented a benefit to the majority of the global population. Perhaps too few of those investigators capable of research in this area were involved in the Conference (Polkowski).

Toxic Pollutants --

Much effort has been expended on removal of the micronutrients, nitrogen and phosphorus. Micronutrients are undoubtedly associated with eutrophication problems and should be thoroughly attended; however, the technology for phosphorus and nitrogen removal appears to be relatively well established. A reorientation of research emphasis to heavy metals, toxic substances and chemical sluges is apparently in order at the international level. Significant contributions have been made in these areas of research in the U.S. and a few well-developed foreign countries, e.g., Japan (Huang).

Wastewater Reclamation --

The topic of water reuse was of considerable interest, and several participants indicated their opinion that total reuse would be common in many areas as water shortages become acute. Thus, the need for water quality management on an international scale is obvious (Krenkel).

The research work for South Africa in water reclamation and reuse, and the projects from Western Europe and Japan relative to unit process applications appear to be more in accordance with our research efforts in the United States, and collaboration with researchers from these areas has been extremely useful (Ford).

Risk Analysis --

One area of research virtually neglected at this Conference concerns environmental risk analysis for chemicals. This is an emerging area that deserves more attention. Tests are being developed throughout the world for use in predicting mobility, transformations, and effects of chemicals in the environment. The results of these tests will be used in assessing the risks associated with new and existing products (Conway).

Water Pollution Control Regulations --

Many Conference participants were interested in the status of water pollution control activities in the U.S. in particular with regard to the effects of Public Law 92-500. Questions posed included whether or not commensurate benefits were being attained with the large expenditures of money, whether the law was working, whether improvement in U.S. water quality was realized, and whether their country should adopt a similar law (Krenkel).

It would appear that Swedish engineers design wastewater treatment facilities to meet BOD and phosphorus standards. All treatment plants are designed with chlorination facilities, but chlorination is applied at the discretion of local public health authorities. Normally chlorine is applied to protect the public engaged in water contact sports (Kerri).

Operator Training --

Norway has discovered that approximately half of their wastewater treatment plants do not perform as intended (similar to the U.S.). An operator training program is being developed and implemented to correct a major source of inadequate plant performance (Kerri).

England has an outstanding operator training program. All agencies and municipalities employing operators of water and wastewater facilities must pay a percentage (approximately 1 percent) of their personnel budget to the government. These funds are used to staff and equip regional training centers. The centers have excellent dormitories (individual rooms, dining halls, recreation facilities and a pub), class rooms and laboratories. Laboratories include instruments for water quality analysis, areas for tapping water lines and sewers, safe trenches to practice shoring, preparing bedding and laying pipe and a 10 m (30 ft) deep manhole with provisions for instructors to observe students working at the bottom of the manhole. The emphasis is on safe procedures and safe conditions and apparently is very effective. Operators are paid their regular wages plus they may receive a portion of their annual bonus early while attending the one- or two-week training sessions. When they return to their regular jobs they are expected to devote an average of 8 hr/week training other operators. Management supports this program (Kerri).

Applied Research --

One of the primary benefits of conferences such as the IAWPR meeting recently completed in Stockholm is in the interfacing of concepts and ideas between individuals. The most constructive comments from several delegates related to encouraging greater emphasis in applied research, namely, research oriented toward solving specific problems, particularly in both industrialized and developing countries. There was a feeling from several conference participants that research efforts in the past have been concentrated in validating highly esoteric models with limited application, and ignoring many of the process variables which influence performance of full-scale treatment facilities (Ford).

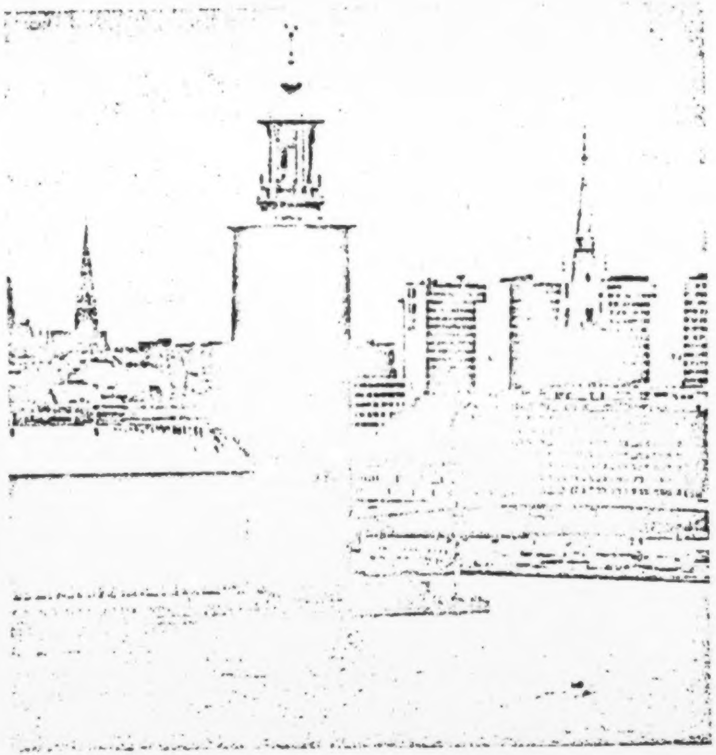
APPENDIX I

FINAL
PROGRAMME

IAWPR

STOCKHOLM
1978

INTERNATIONAL
CONFERENCE



STOCKHOLM SWEDEN
12-16 JUNE 1978

INTERNATIONAL ASSOCIATION ON
WATER POLLUTION RESEARCH
Chichester House, 278 High Holborn, London WC1, U.K.

OUTLINE PROGRAMME

		page
Sunday 11th June		
Commencing at 12 noon	Registration in the Old Parliament Building	4
5.30 p.m.– 7.00 p.m.	Reception by the Conference President	4
Monday 12th June		
10.30 a.m.	Opening of the Conference	4
2.00 p.m.– 4.15 p.m.	Scientific and Technical Sessions	5
7.00 p.m.– 9.00 p.m.	Reception by the City of Stockholm	5
9.00 p.m.– 11.00 p.m.	Optional Excursion—Under the Bridges of Stockholm	5
Tuesday 13th June		
9.00 a.m.– 4.15 p.m.	Scientific and Technical Sessions	6 & 7
9.00 a.m.– 4.00 p.m.	Excursion for family members to Uppsala	7
Wednesday 14th June		
9.00 a.m.– 4.15 p.m.	Scientific and Technical Sessions	8 & 9
10.00 a.m.– 4.00 p.m.	Excursion for family members to Wasa, Waldemarsudde and Skansen	9
6.45 p.m.	Optional visit to Drottningholm Court Theatre	9
Thursday 15th June		
9.00 a.m.– 4.15 p.m.	Scientific and Technical Sessions	10 & 11
7.00 p.m.	Conference Dinner	11
Friday 16th June		
Half-day and full-day technical excursions		12 & 13
From Friday 16th June		
Post Conference Seminars in Sweden, Denmark and Norway		14
Post Conference Tours to Sweden and Norway		15

GENERAL INFORMATION

1. Time and Place

The conference will be held on Monday 12th to Thursday 1
June 1978 inclusive, in the Old Parliament Building (Gamla
Riksdagshuset) in the centre of Stockholm. The opening ce
on Monday morning 12th June at 10.15 a.m. will be in the
Stockholm Concert Hall.

2. Conference Office

The conference offices will be in the Old Parliament Buildin
and will open for registration on Sunday 11th June from 1
to 6.00 p.m. and from Monday 12th to Thursday 15th June
inclusive from 8.30 a.m. to 4.30 p.m. (Tel. (08) 141000).

3. Scientific and Technical Programme

The Scientific and Technical Programme comprises sixty-ei
papers and two workshops. All those who registered for the
Conference in due time will have received by post a compl
of the papers, together with a set of the rules to govern th
conduct of the sessions. Late registrants will receive a set
papers on registration in Stockholm.
The conference will be split into three sessions running
contemporaneously and simultaneous interpretation will be
available in all three sessions in English, French and Germa

4. Technical Excursions

A comprehensive programme of full-day and half-day technic
excursions has been arranged for Friday 16th June 1978. A
set out on pages 12 and 13. Registrants who have not orde
tickets in advance should obtain them from the Technical
Excursion desk.

5. Post-Conference Seminars

A list of the post-conference seminars is set out on page
Places on these seminars should have been reserved in ad
Registrants who have not reserved in advance and are int
in taking part should enquire at the Conference Bureau.

6. Post-Conference Tours

A list of the post-conference tours is set out on page 15.
Places on these tours should have been reserved in advanc
Registrants who have not reserved in advance and are inter
in taking part should enquire at the Conference Bureau.

7. Programme for Family Members

For family members two full-day excursions including lunch
have been arranged. The first, on Tuesday 13th June, is to
famous historical monuments in the old university town of U
and to the tombs of the old Viking kings. The second, on
Wednesday 14th June, is to the Wasa, the Royal Flagship w
sank after launching in Stockholm harbour in 1628; to
Waldemarsudde, home of the late Prince Eugen; and to the
Skansen open-air museum. Tickets for these excursions wil
issued to all registered family members.

8. Social Functions

All registrants and registered family members are invited to
Conference President's reception on Sunday evening 11th Ju
to the Opening Ceremony on Monday morning 12th June
and to the Civic Reception on Monday evening 12th June.
Registrants who wish to attend the Conference Dinner on
Thursday evening 15th June should obtain tickets, price US
each, from the Conference Bureau.
No formal dress is required for the social functions.

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Sunday 11th June 1978

12.00 noon–6.00 p.m.	**Registration in the Old Parliament Building.**
3.00 p.m.–5.00 p.m.	**Optional excursion—Stockholm in a Nutshell** Departure by bus from the Old Parliament Building for sightseeing tour of Stockholm. Tickets, price 25 Skr, can be obtained from RESO at the Conference Bureau.
5.30 p.m.–7.00 p.m.	**Reception by the Conference President** at the Museum of National Antiquities Narvavägen 13–17. All registrants and registered family members are invited.

Monday 12th June 1978

Morning	**Official Opening Ceremony** in the Stockholm Concert Hall. All registrants and registered family members are invited.
10.15 a.m.	Orchestral Performance
10.30 a.m.	Official Opening.

Monday 12th June 1978

Afternoon	**Scientific Sessions in the Old Parliament Building**
HALL A	Chairman: D. E. Weiss (Australia) Recorder: J. Bechaux (France)
2.00 p.m.	*Paper 1*—Carbon Adsorption as an Advanced Wastewater Treatment Process *Author:* Davis L. Ford (U.S.A.) *Discussor:* H. E. Winkler (F.R.G.)
2.45 p.m.	*Paper 4*—The Use of Activated Carbon for Chromium (VI) Removal. *Authors:* C. P. Huang, A. R. Bowers (U.S.A.) *Discussor:* W. J. Weber, Jr. (U.S.A.)
3.30 p.m.	*Paper 7*—Purification of Pulp Bleaching Wastewater with Aluminium Oxide. *Author:* H. Ullrich (F.R.G.) *Discussor:* E. Meloni (Finland)
HALL B	Chairman: Pal Benedek (Hungary) Recorder: Peter Literáthy (Hungary)
2.00 p.m.	*Paper 2*—Study of the Nitrification of Surface Water *Authors:* Y. Richard, L. Brener, G. Martin, C. Leblanc (France) *Discussor:* L. Karlgren (Sweden)
2.45 p.m.	*Paper 5*—The Interrelationships Among Chemical Parameters in Rivers—Analysing the Effect of Natural and Anthropogenic Sources. *Authors:* J. Zobrist, Joan S. Davis (Switzerland) *Discussor:* Paul Koppe (F.R.G.)
3.30 p.m.	*Paper 8*—Mixing Model for Large Streams *Author:* L. Somlyódy (Hungary) *Discussor:* K. Cederwall (Sweden)
HALL C	Chairman: R. Määttä (Finland) Recorder: J. Puolanne (Finland)
2.00 p.m.	*Paper 3*—A Novel Method for Assessing the Thickenability of Sludges *Authors:* M. J. D. White, C. F. Lockyear (U.K.) *Discussor:* R. Ben Aim (France)
2.45 p.m.	*Paper 6*—The Use of Pulped Newsprint as a Conditioning Aid in the Vacuum Filtration of a Municipal Sludge *Authors:* H. W. Campbell, R. W. Kuzyk, G. R. Robertson (Canada) *Discussor:* R. I. Dick (U.S.A.)
3.30 p.m.	*Paper 9*—Properties and Treatment of Lime-Algae Sludge *Authors:* A. Cohen, E. Idelovitch (Israel) *Discussor:* J. Bosman (S.A.)
Evening	
7.00 p.m.–9.00 p.m.	**Civic Reception and Buffet** in the City Hall. Dress: Informal All registrants and registered family members are invited
9.00 p.m.–11.00 p.m.	**Optional Excursion—Under the Bridges of Stockholm.** Departure by boat from the City Hall. Tickets, price 25 SKr, can be obtained from RESO at the Conference Bureau.

Tuesday 13th June 1978

Morning	**Scientific Sessions in the Old Parliament Building**
HALL A	Chairman: B. B. Berger (U.S.A.) Recorder: R. Conway (U.S.A.)
9.00 a.m.	*Paper 10*—A new Concept of Filterability *Author:* K. J. Ives (U.K.) *Discussor:* L. Hallén (Sweden)
9.45 a.m.	*Paper 13*—The Role of Retained Particles in Deep Bed Filtration *Authors:* C. R. O'Melia, W. Ali (U.S.A.) *Discussor:* (U.S.A.)
HALL B	Chairman: S. Iwai (Japan) Recorder: T. Goodgame (U.S.A.)
9.00 a.m.	*Paper 11*—Prediction of Bacterial Pollution in Sea Water *Authors:* T. Omura, J. Matsumoto (Japan) *Discussor:* M. Pinto (Portugal)
9.45 a.m.	*Paper 14*—The Use of Indium 113 for the Measurement of Coefficients of Dispersion in the Sea *Authors:* J. Godin, P. Marchandise, P. J. Rousselin (France) *Discussor:* R. Porte (France)
HALL C	Chairman: E. Märki (Switzerland) Recorder: W. Gujer (Switzerland)
9.00 a.m.	*Paper 12*—Multi-Component Diffusion in Denitrifying Biofilms *Authors:* M. Riemer, P. Harremoes (Denmark) *Discussor:* G. Martin (France)
9.45 a.m.	*Paper 15*—Denitrification Kinetics in a Submerged Rotating Biological Disk Unit *Authors:* Y. Watanabe, M. Ishiguro (Japan) *Discussor:* B. Hultman (Sweden)
10.30 a.m.–11.00 a.m.	**INTERVAL**
HALL A	Chairman: E. J. Hall (S.A.) Recorder: D. M. McCallum (S.A.)
11.00 a.m.	*Paper 16*—Particulates and Trace Pollutant Removal by Depth Filtration *Authors:* M. C. Kavanaugh, Moon Chung, E. A. Pearson (U.S.A.), G. Toregas (Greece) *Discussor:* S. Almeida (Brazil)
11.45 a.m.	*Paper 19*—Removal of Residual Phosphorous and Suspended Solids by Contact Filtration *Author:* L. Pelloni (Switzerland) *Discussor:* J. Bébin (France)
HALL B	Chairman: K. Baalsrud (Norway) Recorder: L. Vråle (Norway)
11.00 a.m.	*Paper 17*—Mathematical Modelling of Eutrophied Coastal Areas *Author:* K. I. Dahl-Madsen (Denmark) *Discussor:* M. J. Barrett (U.K.)
11.45 a.m.	*Paper 20*—Water Conditions in the Stockholm Archipelago after the introduction of Biological and Chemical Purification of Wastewater *Authors:* M. Cronholm, K. Bennerstedt (Sweden) *Discussor:* E. A. Pearson (U.S.A.)
HALL C	Chairman: P. H. Jones (Canada) Recorder: H. W. Campbell (Canada)
11.00 a.m.	*Paper 18*—Treatment of High Nitrate Wastewaters by Plastic Media Anaerobic Filters with Particular Reference to Latex Processing *Authors:* G. K. Anderson (U.K.), A. B. Ibrahim (Malaysia) *Discussor:* F. Pohland (U.S.A.)
11.45 a.m.	*Paper 21*—Denitrification of a Concentrated Nitrogenous Industrial Effluent using Packed Column and Fluidised Bed Reactors. *Authors:* J. Bosman, A. Eberhard, C. Baskir (S.A.) *Discussor:* H. Moreaud (France)

Tuesday 13th June 1978

9.00 a.m.–4.00 p.m. *Family Members' Excursion to Uppsala*
Departure from the Old Parliament Building

12.30 p.m.–2.00 p.m. **LUNCHEON BREAK**

Afternoon **Scientific Sessions in the Old Parliament Building**

HALL A **Chairman:** L. Coin (France)
Recorder: C. Basalo (France)

2.00 p.m. *Paper 22*—**Heavy Metals in Soil and Cereals Fertilized with Sewage Sludge**
Author: I. Viitasalo (Finland)
Discussor: A. Kinmont (S.A.)

2.45 p.m. **WORKSHOP on Problems in the Application and Development of New Technologies.**
Convener: A. W. Breidenbach (U.S.A.)
Recorder: R. Canham (U.S.A.)
Nominated Speakers: J. Bernard (France), P. E. Odendaal (S.A.), S. Iwai (Japan) A. W. Breidenbach (U.S.A.)

HALL B **Chairman:** M. E. Upcott Taylor (N.Z.)
Recorder: G. D. Roberts (U.K.)

2.00 p.m. *Paper 23*—**Microbiological Quality Indicators for Routine Monitoring of Wastewater Reclamation Systems**
Authors: W. O. K. Grabow, B. W. Bateman, J. S. Burger (S.A.)
Discussor: N. Bruce Hanes (U.S.A.)

2.45 p.m. *Paper 25*—**Further Studies in Bifidobacteria as Indicators of Faecal Pollution in Water.**
Authors: L. M. Evison, S. Morgan (U.K.)
Discussor: W. O. K. Grabow (S.A.)

3.30 p.m. *Paper 27*—**Relationship Between Indicator Organisms and Selected Pathogenic Bacteria in Urban Waterways**
Authors: V. P. Olivieri, K. Kawata, C. W. Krusé (U.S.A.)
Discussor: C. D. Parker (Australia)

HALL C **Chairman:** K. R. Imhoff (F.R.G.)
Recorder: P. Koppe (F.R.G.)

2.00 p.m. *Paper 24*—**The Role of Sediments on Mercury Transport (total- and methyl-) in a River System**
Authors: A. Kudo, D. R. Miller, H. Akagi, D. C. Mortimer, H. Nagase, D. R. Townsend, R. G. Warnock (Canada)
Discussors: P. A. Krenkel and R. S. Reimers (U.S.A.)

2.45 p.m. *Paper 26*—**The Uptake and Release of Petroleum Hydrocarbons by the Marine Mussel Mytilus Edulis**
Authors: N. Hansen, V. B. Jensen, H. Appelquist, E. Morch (Denmark)
Discussor: J. Hemens (S.A.)

3.30 p.m. *Paper 28*—**Accumulation of Bioresistant Micropollutants in a Particular Catchment in Hungary**
Authors: P. Literáthy , F.Laszió (Hungary)
Discussor: H. Fish (U.K.)

Evening Free.

Wednesday 14th June 1978

Morning Scientific Sessions in the Old Parliament Building

HALL A **Chairman:** P. Isaac (U.K.)
Recorder: K. Ives (U.K.)

9.00 a.m. *Paper 29*—The Effect of Diurnal Ammonium Load Variation on the Performance of Nitrifying Activated Sludge Processes
Authors: W. Gujer, P. Erni (Switzerland)
Discussor: M. Picard (France)

9.45 a.m. *Paper 32*—Consistent Biological Phosphate and Nitrate Removal in an Activated Sludge Plant
Authors: M. J. Simpkins, A. R. McLaren (S.A.)
Discussor: Y. Watanabe (Japan)

HALL B **Chairman:** I. Larsen (Sweden)
Recorder: A. Sjöberg (Sweden)

9.00 a.m. *Paper 30*—The Thames Model: An Assessment
Authors: M. J. Barrett, B. M. Mollowney, P. Casapieri (U.K.)
Discussor: H. Hahn (F.R.G.)

9.45 a.m. *Paper 33*—Application of a Mathematical Model to the Characterization of Dispersion Effects on Groundwater Quality
Authors: P. Peaudecerf, J. P. Sauty (France)
Discussor: K. Poeppinghaus (F.R.G.)

HALL C **Chairman:** E. Kuntze (F.R.G.)
Recorder: H. Bernhard (F.R.G.)

9.00 a.m. *Paper 31*—The Impact of Atmospheric Contaminants on Storm Water Quality in an Urban Area
Authors: C. W. Randall, D. R. Helsel, T. J. Grizzard (U.S.A.)
Discussor: G. Svensson (Sweden)

9.45 a.m. *Paper 34*—Atmospheric Contaminants, Fallout and their Effects on Storm Water Quality.
Author: A. Goettle (F.R.G.)
Discussor: E. Ottmann (F.R.G.)

10.30 a.m.–11.00 a.m. **INTERVAL**

HALL A **Chairman:** G. Shelef (Israel)
Recorder: A. Wachs (Israel)

11.00 a.m. *Paper 35*—Design Considerations for Integrated Nutrient Removal Systems
Authors: P. M. Sutton, K. L. Murphy, B. E. Jank (Canada)
Discussor: N. Matsché (Austria)

11.45 a.m. *Paper 38*—Alkalinity—A Neglected Parameter in Advanced Wastewater Treatment Systems
Authors: M. Nielsen, E. Bundgaard (Denmark)
Discussor: W. Stumm (Switzerland)

HALL B **Chairman:** L. Mendia (Italy)
Recorder: M. Gerletti (Italy)

11.00 a.m. *Paper 36*—The Effects of the Disposal of Effluents and Sewage Sludge on Groundwater Quality in the Chalk of the United Kingdom
Authors: K. J. Edworthy, W. B. Wilkinson, C. P. Young (U.K.)
Discussor: H. Shuval (Israel)

11.45 a.m. *Paper 39*—Simultaneous *in situ* Determination of Dissolved Nitrogen and Oxygen by Gas Chromotography
Authors: T. Bilstad (Norway), E. N. Lightfoot, L. B. Polkowski (U.S.A.)
Discussor: P. Literáthy (Hungary)

HALL C **Chairman:** P. Fouquet (France)
Recorder: R. Cabridenc (France)

11.00 a.m. *Paper 37*—Atmospheric Fallout and Street Cleaning —Effects on Urban Storm Water and Snow
Author: P. A. Malmquist (Sweden)
Discussor: M. Melanen (Finland)

Wednesday 14th June 1978

11.45 a.m. *Paper 40*—**Urban Runoff from a Road Surface—A Water Quality Study**
Authors: W. Pope, N. J. D. Graham, R. J. Young, R. Perry (U.K.)
Discussor: M. Ishiguro (Japan)

10.00 p.m.–4.00 p.m. *Family Members' Excursion to Wasa and Skansen*
Departure from the Old Parliament Building

12.30 p.m.–2.00 p.m. **LUNCHEON BREAK**

Afternoon **Scientific Sessions in the Old Parliament Building**

HALL A **Chairman:** S. Hallquist (Sweden)
Recorder: T. Ax (Sweden)

2.00 p.m. *Paper 41*—**The Effect of Petrochemical Structure on Methane Fermentation Toxicity**
Authors: W. Lin Chou, R. E. Speece, K. McKeon (U.S.A.), R. H. Siddiqi (Saudi Arabia)
Discussor: A. Wienhusen (F.R.G.)

2.45 p.m. **WORKSHOP on Water Pollution Problems Arising from Development**
Convener: W. J. Cosgrove (U.S.A.)
Recorder: T. Delloua (Tunisia)
Nominated Speakers: J. B. Mendis (Bangladesh), D. R. Ellis (U.K.), A. B. Redekopp (Canada), U. P. Gibson (U.S.A.), De Anne Julius (U.S.A.), C. Gunnerson (U.S.A.)

HALL B **Chairman:** H. Fleckseder (Austria)
Recorder: G. Usrael (Austria)

2.00 p.m. *Paper 42*—**Removal of Organic Dyes by Activated Sludge**
Authors: M. Dohányos, V. Madéra, M. Sedlácek (Czechoslovakia)
Discussor: H. Björndahl (Sweden)

2.45 p.m. *Paper 44*—**Retention of Viruses During Sludge Application to Soils**
Authors: G. Bitton, O. C. Pancorbo, A. R. Overman, G. E. Gifford (U.S.A.)
Discussor: E. Lund (Norway)

3.30 p.m. *Paper 46*—**Survival of Poliovirus in Model Wastewater Holding Ponds**
Authors: S. Funderburg, B. E. Moore, C. A. Sorber, B. P. Sagik (U.S.A.)
Discussor: M. Bouteille (France)

HALL C **Chairman:** A. van Haute (Belgium)
Recorder: D. Wilms (Belgium)

2.00 p.m. *Paper 43*—**The Significance of Plant Nutrient Yields in Runoff from a Mixed Land Use Watershed**
Authors: T. J. Grizzard, C. W. Randall, R. C. Hoehn, K. G. Saunders (U.S.A.)
Discussor: D. F. Toerien (S.A.)

2.45 p.m. *Paper 45*—**Determining Nutrient Loading from Rainfall and Runoff in Small Rivers**
Author: H.-R. Verworn (F.R.G.)
Discussor: E. Isgård (Sweden)

3.30 p.m. *Paper 47*—**Nutrient Budget for a Residential Stormwater Catchment in Durban, South Africa**
Authors: D. E. Simpson, J. Hemens (S.A.)
Discussor: P. Stahre (Sweden)

Evening **Drottningholm Court Theatre**
6.45 p.m. By boat from Klara Mälrstrstrand (close to the City Hall) to Drottningholm Palace for a performance at the 18th-century theatre by artists from the Royal Opera in Stockholm. Return by bus to City Centre at approx. 9.30 p.m. Tickets, price 100 SKr, can be obtained from RESO at the Conference Bureau.

Thursday 15th June 1978

Morning **Scientific Sessions in the Old Parliament Building**

HALL A **Chairman:** F. Valiron (France)
Recorder: M. Daniel (France)

9.00 a.m. *Paper 43*—Chemical Precipitation of Wastewater with Lime and Seawater
Author: L. Vråle (Norway)
Discussor: G. Bossy (France)

9.45 a.m. *Paper 51*—Experiences and Process Development in Biological—Chemical Treatment of Municipal Wastewaters in Sweden
Authors: S. Grönqvist, H. Holmström, B. Hultman, L. G. Reinius (Sweden)
Discussor: J. Nesbitt (U.S.A.)

HALL B **Chairman:** G. G. Cillié (S.A.)
Recorder: H. C. Stegmann (S.A.)

9.00 a.m. *Paper 49*—Ozone Initiated Oxidations of Solutes in Wastewater: A Reaction Kinetic Approach
Authors: J. Hoigné, H. Bader (Switzerland)
Discussor: A. Wachs (Israel)

9.45 a.m. *Paper 52*—Rapid Appraisal of the Effects of Various Substances on Microorganisms
Authors: P. H. Brouzes, A. De Pierrefeu, J.-Y. Bernhard, C. Racle (France)
Discussor: R. Chalmers (U.K.)

HALL C **Chairman:** P. Harremoes (Denmark)
Recorder: M. Riemer (Denmark)

9.00 a.m. *Paper 50*—A Study of Stormwater Runoff Quality
Authors: W. G. Characklis, P. B. Bedient, F. G. Gaudet, F. L. Roe (U.S.A.)
Discussor: D. Orhon (Turkey)

9.45 a.m. *Paper 53*—A Mass Balance Method for Estimating Combined Sewer Runoff and Overflow Quality from Sewage Treatment Plant Data
Authors: J. A. Mueller, A. R. Anderson (U.S.A.)
Discussor: J. Ellis (U.K.)

10.30 a.m.–
11.00 a.m. **INTERVAL**

HALL A **Chairman:** D. Stephan (U.S.A.)
Recorder: (U.S.A.)

11.00 a.m. *Paper 54*—Basis for the Design of Alternative Chemical-Biological Wastewater Treatment Processes
Authors: W. Gujer, M. Boller (Switzerland)
Discussor: Bjorn Rosén (Sweden)

11.45 a.m. *Paper 57*—Physical Chemical Treatment of Anaerobic Filter Effluent
Authors: F. B. DeWalle, E. S. K. Chian (U.S.A.)
Discussor: A. Wachs (Israel)

HALL B **Chairman:** G. R.-Mijares (Venezuela)
Recorder: D. Macleod (S.A.)

11.00 a.m. *Paper 55*—Immediate and Continuous Measurement of Activated Sludge Quantity in Sewage Biological Treatment Tanks
Author: J. Durot (France)
Discussor: T. Markkanen (Finland)

11.45 a.m. *Paper 58*—Wastewater Control Technology in Steam-Electric Power Plants
Authors: Tien-Tung J. Chu, P. A. Krenkel, R. J. Ruane (U.S.A.)
Discussor: N. Lever (S.A.)

HALL C **Chairman:** R. Ludwig (Brazil)
Recorder: I. Hespanhol (Brazil)

11.00 a.m. *Paper 56*—Comparative Assessment of Pollution Loadings from Non-Point Sources in Urban Land Use
Authors: V. Novotny, J. Goodrich-Mahoney (U.S.A.)
Discussor: H. Ludwig (Brazil)

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Thursday 15th June 1978

11.45 a.m. *Paper 59*—Design of Teacup Solids Separators for Treatment of Sewer Overflows
Authors: K. D. Kerri, A. L. Prasuhn, G. E. Wilson (U.S.A.)
Discussor: G. Roberts (U.K.)

12.30 p.m.– **LUNCHEON**
2.00 p.m. **BREAK**

Afternoon **Scientific Sessions in the Old Parliament Building**

HALL A **Chairman:** J. Salloum (Canada)
Recorder: P. E. Odendaal (S.A.)

2.00 p.m. *Paper 60*—Trace Metal Removal from Secondary Effluent by Two-Stage High Lime-Magnesium Treatment
Authors: E. Idelovitch, M. Michail (Israel)
Discussor: O. Hart (S.A.)

2.45 p.m. *Paper 63*—Domestic Wastewater Treatment with Oxidation Ponds in Combination with Chemical Precipitation.
Authors: P. Balmér, B. Vik (Norway)
Discussor: C. D. Parker (Australia)

3.30 p.m. *Paper 66*—Improvement of the Quality of Waste Pond Effluents in Northern Areas by Chemical Pre-Precipitation
Author: J. U. Airaksinen (Finland)
Discussor: P. Rantala (Finland)

HALL B **Chairman:** S. Björk (Sweden)
Recorder: A. Hilmer (Sweden)

2.00 p.m. *Paper 61*—Effect of Nitrification in Orta Lake
Authors: M. Gerletti, A. Provini (Italy)
Discussor: P. A. Krenkel (U.S.A.)

2.45 p.m. *Paper 64*—Restoration of Lake Nakskov Indrefjord, Denmark, Using Algal Ponds to Remove Nutrients from Inflowing River Water
Authors: N. Nyholm, P. E. Sorensen, K. Olrik, S. D. Pedersen (Denmark)
Discussor: J. Rennerfelt (Sweden)

3.30 p.m. *Paper 67*—The Significance of Sewage Effluent for the Hydraulic and Nutrient Loads on Lakes.
Author: S.-O. Ryding (Sweden)
Discussor: H. C. Stegmann (S.A.)

HALL C **Chairman:** A. Kavonius (Finland)
Recorder: E. Meloni (Finland)

2.00 p.m. *Paper 62*—Influence of Oxydising Treatments on the Formation and the Degradation of Haloform Reaction Precursors
Authors: M. Dore, N. Merlet, T. Blanchard, B. Langlais (France)
Discussor: J. Hoigné (Switzerland)

2.45 p.m. *Paper 65*—Chlorinated and Brominated Lipophilic Substances in Spent Bleach Liquors from a Sulfite Pulp Mill
Author: D. Dyrssen (Sweden)
Discussor: H. Eisenhauer (Canada)

3.30 p.m. *Paper 68*—The Effect of Process Configuration on the Formation of Volatile Organohalogen Compounds in Reclaimed Water
Author: O. O. Hart (S.A.)
Discussor: C. Gomella (France)

Evening
7.00 p.m. Conference Dinner and Dance in the City Hall
Dress: Informal
Tickets, price US$40 per person, must be obtained from RESO at the Conference Bureau.

Friday 16th June 1978

TECHNICAL EXCURSIONS

All technical excursions will leave from the Old Parliament Building with the exception of TE9 which will leave from Nybrokajen (Strand Hotel).
Technical Excursions TE1 to TE6 are half-day and will be available both in the morning and afternoon.
There is no charge to registrants or registered family members.
Technical Excursions TE8 to TE10 are full-day, inclusive of lunch, and tickets must be ordered and paid for in advance.
Registrants may therefore choose either two half-day excursions from TE1 to TE6 or one full-day excursion from TE8 to TE10.

TE1 Käppala Sewage Works (Half-day)

8.30 a.m. and 1.30 p.m.

Nine municipalities situated north of Stockholm have formed a joint municipal authority, Käppalaförbundet, which collects the sewage in rock tunnels of a total length of 60 km and conveys it to a sewage treatment plant on the island of Lidingö in the archipelago of Stockholm. The sewage treatment plant has a capacity of 280 000 m^3/d. Purification is by activated sludge and chemical pre-precipitation using ferrous sulphate. It serves a population of about 280 000 persons and deals with a load of about 390 000 population equivalents.

TE2 Henriksdal Sewage Treatment Plant (Half-day)

8.15 a.m. and 1.30 p.m.

The Henriksdal sewage treatment plant is the biggest of Stockholm's four plants. It is blasted out of rock and has mechanical-chemical pre-precipitation and activated sludge treatment. The plant has a capacity of 370 000 m^3/d and receives sewage from about 530 000 persons. The Water Court requires that in dry weather under normal conditions the plant must give a minimum of 95% reduction of the BOD and 90% reduction of the total phosphorous. During 1976 effluent averaged 18 mg BOD_7/l (91% reduction) and 0,55 mg total P/l (92% reduction).

TE3 Himmerfjärden Sewage Treatment Plant

(Half-day) 8 a.m. and 1.30 p.m.

The sewage from three municipalities south-west of Stockholm is treated at one regional plant, built and run by the South-western Stockholm Regional Water and Sewerage Works Inc., SYVAB. Commissioned in 1974, the plant treats the sewage from about 150 000 persons and has a capacity of more than 200 000 m^3/d. The installation consists of more than 40 km tunnels in rock and of a plant at Himmerfjärden (a bay of the Baltic) which uses activated sludge followed by chemical treatment. During 1976 the average BOD_7 was 6 mg/l (98% reduction), and the phosphorous approximately 0,7 mg/l (91% reduction).

TE4 Norsborg Water Treatment Plant (Half-day)

9 a.m. and 2 p.m.

The fresh water supply to Stockholm and to seven neighbouring municipalities is derived from surface water from Lake Malaren. To produce drinking water Stockholm has two waterworks, Lovö and Norsborg, with a total capacity of more than 800 000 m^3/24 h. At Norsborg there are two installations: the western works dating from the turn of the century and modernised in the 1950's, and the eastern works dating from 1975. Purification is carried out by chemical treatment and by rapid and slow sand filtration. The installation to be visited is the eastern works, which has modern technical equipment including a computer.

TE5 Sollelund Sanitary Land Fill for Solid Wastes and Sludge (Half-day) 9 a.m. and 2 p.m.

This landfill at Huddinge, south of Stockholm, receives domestic, trade and industrial waste, together with building site rubbish and dewatered sludge. Södertörns Renhallningsverk AB (Södertörn Sanitary Company), SRV, which operates the plant, has adopted an environmental protecting process which provides for recovery of waste materials. The plant is able to mill 120 000 tons of refuse per annum which is mixed with 80 000 tons of sludge from sewage treatment plants. Refuse from about 200 000 persons and sludge from about 360 000 persons are treated at the plant.

TE6 Pripps Brewery (Half-day) 9 a.m. and 2 p.m.

AB Pripps Bryggerier, the main brewing company in Sweden, has 9 breweries and 2 maltings. The brewery in Bromma is the largest with a production capacity of 200 000 m³ beer and soft drinks annually. The brewery was built in 1970. During the first year the brewery was in operation, the amount of pollution was surprisingly high (yielding 12 kg BOD per m³ product). With internal measures the load of pollution has been reduced to about 4 kg BOD per m³ product. The volume of effluent produced has been reduced since that time from 5 to 3 m³ per m³ product.

TE8 Lake Restoration (Full-day) 9 a.m.

In the Stockholm region the discharge of stormwater and sewage overflow is a source of pollution. For the 16 small lakes of the Municipality of Stockholm the first stage of a restoration programme approved by the Municipal Council in 1974 provides for the restoration of four, and possibly six, lakes. Restoration has already been carried out in the lakes Trehörningen (in Huddinge), Osbysjön (in Danderyd) and Brunnsviken (in Stockholm-Solna).
An account will be given of the lake restoration programme for Stockholm followed by a visit to the above-mentioned lakes. An all-day tour by bus, picnic lunch and refreshments included.
Price: US$20.

TE9 Stockholm Archipelago (Full-day) 10 a.m.

The archipelago of Stockholm with about 24 000 islands has great importance as a recreation area for the inhabitants of Greater Stockholm. The eastern part of Lake Mälaren, which has its main outflow to the archipelago, and the inner part of the archipelago are the receiving waters for the sewage of the region. The control of the receiving waters, which has been continuous since the end of the 19th century is vested in the Stockholm Water and Sewage Works which uses a sampling boat fitted out for the purpose.
An excursion by boat with a description of the archipelago and its marine state. The sampling boat will be seen in action. Picnic lunch and refreshments included.
Price: US$35.

TE10 Forsmark Nuclear Power Plant (Full-day) 8.30 a.m.

An all-day excursion by bus to Forsmark, about 130 km north of Stockholm, where a reactor of 800 MW is expected to start shortly. Before being discharged to the Baltic the cooling-water, raised in temperature, will first pass to a unique physical, chemical and biological testing basin with an area of one square kilometre. This installation will provide valuable information useful for control, investigation and researc concerning the effects of cooling-water and radio-active discharges on the ecology of the receiving water.
The excursion includes lunch at Forsmark Mansion, which dates from the 18th century, and a visit to Old Upsala, where three buri mounds of unknown kings from the Viking age are to be seen.
Price: US$35.

POST-CONFERENCE SEMINARS

PS1 Kinetics of Wastewater Treatment

Denmark—Monday 19th to Wednesday 21st June
During the last two decades the design and operation of wastewater treatment plants have been improved considerably due to conceptual approaches to an understanding of the phenomena involved. Such approaches are still developed based on fundamental concepts and on kinetic simulation of the physical, chemical and microbiological phenomena involved. The purpose of the seminar is to bring together scientists who are involved in research on the borderline of our understanding of the phenomena for a fruitful exchange of ideas and experiences. The seminar focuses on the fundamentals of the unit processes involved with the implicit aim to make basic concepts available for practical application.

Organiser: Professor P. Harremoes, Department of Sanitary Engineering, Technical University of Denmark, Building 115, DK 2800 Lyngby. Telephone: (01) 884200.

Price: 260 Danish Kroner (US$40).
Non-members 340 Danish Kroner (US$55).

PS3 Eutrophication of Deep Lakes

Strand Hotel, Gjövik, Norway—Monday 19th and Tuesday 20th June
The intentions of the seminar are to have an up-to-date discussion on the scientific fundamentals of eutrophication in large and deep lakes. Presentations will be given by invited scientists. The results of various measures against eutrophication of lakes will be reviewed and followed by a discussion of the prospects of further research as well as of lake water quality management.

Organiser: The Norwegian Committee of IAWPR, c/o Norwegian Institute for Water Research, PO Box 333, Blindern, Oslo 3. Telephone: (02) 23 52 80.

Price: 470 Norwegian Kroner (US$90).
Non-members 570 Norwegian Kroner (US$110).

PS4 Water Pollution Control in Pulp and Paper Industries

Stockholm—Friday 16th and Saturday 17th June
On Friday there will be lectures and discussions covering the problems of pulp and paper production from a water pollution point of view and the most recent ways to solve these problems. On Saturday there will be a study visit to a modern Swedish pulp mill.

Organiser: IVL (Swedish Water and Air Pollution Research Institute), Box 21060, S-100 31 Stockholm, Sweden. Telephone: (08) 24 96 80. Telex: 11792 IVL.

Price: 430 Swedish Kronor (US$90).
Non-members 500 Swedish Kronor (US$105).

18/13

POST-CONFERENCE TOURS

To enable all participants in the 9th IAWPR Conference to visit places and plant of scientific interest and to see something of the beauty and variety of Scandinavia, a number of post-conference tours have been organised.

PT1 and PT2 Northern Sweden

Lapland, a huge area extending well beyond the Arctic Circle, readily captures the imagination of visitors. A Lapland phenomenon is the Midnight Sun which drops to the horizon but never dips below it, casting its eerily beautiful light across the landscape, turning night into day for a period of full six weeks from the end of May to the middle of July. A choice of two tours is offered.

PT1 12-Hour Night Tour
Departure in the evening of Friday 16th June for a 12-hour exciting Midnight Sun Adventure including a Midnight Sun Supper and a visit to the Lapp village Jukkasjärvi. Return to Stockholm in the morning of 17th June.

PT2 2-Day Tour
Departure in the evening of Friday 16th June by jet to Kiruna, the world's largest city, incorporating an area of 20 000 km² but with a population of less than 30 000. Visits will be made to the iron mine—one of the world's largest iron deposits, a Lapp village (Jukkasjärvi) as well as sightseeing in Kiruna. Information on sewage treatment in cold climates will be presented. The tour includes accommodation for 2 nights and full board, the services of a tour guide in Kiruna and the transportation by jet and bus. Return to Stockholm in the afternoon of 18th June.

Organiser: RESO Congress Service, S-10524 Stockholm, Sweden. Telephone: (08) 22 60 20. Telex: 1805.

Price: PT1 1025 Swedish Kronor (US$215).
PT2 1325 Swedish Kronor (US$275).

PT4 Norway—Mountains and Fjords—3-Day Tour

A cross-country tour by private motor coach with a tourist guide and an expert on water management and water pollution problems. The tour will provide several opportunities to observe pollution and water management problems of rivers, lakes and fjords. The tour will pass through famous tourist areas at mountains, glaciers, waterfalls and typical Norwegian fjord country. Industrial towns at Drammen, Kongsberg, Rjukan and Odda will be included in the tour. Two overnight stops in the mountains. Departure from Oslo on Sunday 18th June in the morning and concluding in the afternoon or evening of Tuesday 20th June. Overnight train for return to Oslo if desired.

Organiser: The Norwegian National Committee of IAWPR, c/o Norwegian Institute for Water Research, PO Box 333, Blindern, Oslo 3, Norway. Telephone (02) 23 52 80.

Price: Approx. 1000 Norwegian Kroner (approx. US$190).

INTERNATIONAL ASSOCIATION
ON
WATER POLLUTION RESEARCH
(IAWPR)

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*Dr. G. J. Stander—Past President (South Africa)
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*Dr. S. H. Jenkins—Executive Editor (United Kingdom)
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*Prof. Dr. W. von der Emde (Austria)
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Mr. J. E. Lind (Secretary)

RID
5-24-78

APPENDIX II

Assignments - Participants in USANC Project

Day	Hall A	Hall B	Hall C
Monday - p.m.	O'Melia	Krenkel	Randall
Tuesday - a.m.	Weber	Hanes	Ford
Tuesday - p.m.	* Goodgame (workshop only)	Bitton	Pohland
Wednesday - a.m.	Speece	Novotny	DeWalle
Wednesday - p.m.	* Canham (workshop only)	Mueller	Kerri
Thursday - a.m.	Kavanaugh	Conway	Berger
Thursday - p.m.	Haung	Polkowski	Molof

* Papers 41 and 22 - Sajik

APPENDIX III

UNITED STATES OF AMERICA NATIONAL COMMITTEE

For representation of the United States to the

INTERNATIONAL ASSOCIATION ON WATER POLLUTION RESEARCH

Chairman
DR. RICHARD I. DICK (A.E.E.P.)
Department of Civil Engineering
University of Delaware
Newark, Delaware 19711
(302) 738-2431
Vice-Chairman
DR. DAVID G. STEPHAN (A.I.Ch.E.)
Industrial Environmental Research Lab
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268
(513) 684-4402
Secretary-Treasurer
DR. RICHARD S. ENGELBRECHT (W.P.C.F.)
Department of Civil Engineering
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801
(217) 333-3822

MEMORANDUM

DATE: May 25, 1978

TO:

FROM: Richard I. Dick, Chairman

SUBJECT: Assignments for Development of USANC Report on Stockholm Conference

The Coordinating Subcommittee for preparing USANC's analysis of developments at the IAWPR Conference in Stockholm has assigned sessions to be covered by participants in the project. Your assignment is to prepare a penetrating analysis of developments at the following session:

Date: ______________

Hall: ______________

Time: ______________

The Subcommittee regrets that the expressed preferences of all participants for particular sessions could not be accommodated.

It is essential that you contact one of the members of the USANC Coordinating Subcommittee soon after you arrive in Stockholm. The purpose is to verify your presence and to learn of any necessary changes in assignments.

SPONSORING ORGANIZATIONS

ASSOCIATION OF ENVIRONMENTAL ENGINEERING PROFESSORS **AMERICAN CHEMICAL SOCIETY**
AMERICAN INSTITUTE OF CHEMICAL ENGINEERS **AMERICAN SOCIETY OF CIVIL ENGINEERS** **WATER POLLUTION CONTROL FEDERATION**

9th International Conference on Water Pollution Research, Stockholm, Sweden - June 12-16, 1978

The members of the Subcommittee are:

Richard I. Dick
Richard Engelbrecht
Jack Nesbitt
David Stephan

Guidelines for preparation of individual reports are enclosed. Inasmuch as each individual's report will appear in the overall project report, it is essential that the guidelines be followed closely. Note particularly the deadline (July 17, 1978) for submission of reports - to achieve maximum value to EPA, the report must be submitted soon after the conference.

It is emphasized that each individual's report is to be an interpretive analysis of developments at the conference. Proceedings - including discussions - will be published by IAWPR, and these will serve as an objective record of the technical details presented at the conference. Your report need not, therefore, include the detailed information that will be contained in the Conference Proceedings. What is needed for the USANC report is an assessment of the significance of the presentations and information related to the presentations which will not be found in the conference proceedings. Such information might, for example, come from personal discussions with authors or contributors to discussions. I've asked USANC Secretary-Treasurer Engelbrecht to send a copy of the USANC report on developments at the 1976 IAWPR Sydney Conference to participants who have not previously received a copy. Additionally, an illustrative individual report from that document is enclosed.

In addition to coverage of the assigned session, participants are specifically requested to report pertinent developments at the conference which do not occur during the technical sessions (see Section VI of the outline for individual reports). Enclosed is the entire section of the report on the 1976 Conference which concerned developments outside of the technical sessions. Please look it over to gain an idea of the type of information desired. It is hoped that this section of the report on the Stockholm Conference can be expanded over that for Sydney.

Information on compensation for services and expenses is included in the guidelines. Note in particular that experience with the Sydney report resulted in implementation of rigid financial motivations for submission of reports prior to the deadline. Internal Revenue Service regulations on deducting expenses for attending foreign conferences have changed recently - a copy of those regulations as contained in the 1977 version of the Federal Income Tax Forms booklet is enclosed for your information.

Notice was received from EPA today that the USANC proposal for developing the Stockholm report has been funded.

RID:add

GUIDELINES

for

PREPARATION OF INDIVIDUAL REPORTS

on

DEVELOPMENTS AT THE NINTH INTERNATIONAL CONFERENCE ON WATER POLLUTION RESEARCH
STOCKHOLM, SWEDEN

June 12-16, 1978

Emphasis of Report

USANC's report to EPA on developments at the IAWPR Conference in Stockholm is not intended to be simply a record of the Conference. Instead, an interpretive analysis of significant developments at the conference is required. This penetrating assessment is to be developed not only by critical analysis of papers and formal and informal discussions at the technical sessions, but also by inclusion of insights gained through more informal contacts with Conference participants.

The positive aspects of Conference developments should be emphasized (what did you learn that is important to United States water pollution research activities?). Don't dwell on criticism of papers which you feel to be inferior, and don't give much space to papers which are not pertinent to problems in the United States. Don't include information of limited significance such as how many people attended a session, how well the session chairman performed, etc.

Distribution

The report will be distributed at least within EPA, to USANC Sponsoring Organizations and USANC committee members, and to participants in the report development. The report also will be made available to the public through the National Technical Information Service. Bylines will be included to acknowledge the authorship of reports on individual sessions.

Length

Individual reports on sessions are to be as short or long as necessary to adequately describe pertinent developments. It is not necessary to give equal attention to each paper. Space in the report should be allocated on the basis of relevance to U.S. water pollution control problems and water pollution research activities. It is anticipated that the average length of individual session reports will be a tightly written 6 to 10 double-spaced pages, but don't unnecessarily expand or condense a concise, penetrating report merely to achieve that length.

Format

The organization and content of the individual reports is to be as indicated in the outline included as Attachment I. Note that the last section of the report provides an opportunity to record observations which do not relate to your assigned session and that it should begin on a separate sheet of paper. These contributions from all participants will be combined.

Metric units should be used, and the editorial standards for Water Research (included as Attachment II) should be observed.

Submission

Individual reports are to be submitted in double-spaced typed finished form. Four copies of reports are to be submitted by July 17, 1978 to:

Richard I. Dick
Department of Environmental Engineering
Hollister Hall
Cornell University
Ithaca, New York 14853

Prompt submission of reports is essential. As indicated in the following section, reimbursement for late reports will be at a reduced level and no reimbursement will be made for reports received after August 5, 1978.

Compensation

Compensation will be on the basis of a submitted statement for services and expenses. As indicated in earlier correspondence, no reimbursement for international travel can be allowed. A maximum level of reimbursement will be established based on available funds, cost sharing requirements, and demands on available funds. Reimbursement will be contingent upon receipt of an acceptable report prior to the deadline. Furthermore, because the maximum allowable level of compensation will depend on the magnitude of the total requests for compensation, no payments can be made until all reports are approved (one individual may hold up all payments). Requests for reimbursement are to be sent to the USANC Secretary-Treasurer, R. S. Engelbrecht, Use the expense voucher included as Attachment III for this purpose.

Reimbursement for acceptable reports received after July 25, 1978 will be reduced by 50 percent. No reimbursement will be made for reports received after August 5, 1978.

Coordinating Subcommittee

Development of these guidelines, review and acceptance of individual reports and preparation of the final EPA report is being coordinated by a U. S. A. National Committee Coordinating Subcommittee consisting of:

Richard I. Dick
Department of Environmental Engineering
Cornell University
Ithaca, New York 14853
Phone: (607)256-3648

Richard Engelbrecht
Department of Civil Engineering
University of Illinois
Urbana, Illinois 61801
Phone: (217)333-3822

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116 Sackett Building
Pennsylvania State University
University Park, Pennsylvania 16802
Phone: (814)865-1226

David Stephan
Industrial Environmental Research Lab
Environmental Protection Agency
Cincinnati, Ohio 45268
Phone: (513)684-4402

Additional information concerning this USANC activity may be obtained from any of the Subcommittee members.

OUTLINE FOR INDIVIDUAL REPORTS ON DEVELOPMENTS AT STOCKHOLM IAWPR CONFERENCE

*I. SESSION

- *A. Day, Hall, Time
- *B. Theme of Session (a few words describing the major orientation of papers--e.g., "Marine Disposal" or "Sludge Thickening and Dewatering")

*II. REVIEWER

- *A. Name
- *B. Position and Affiliation

*III. REVIEW OF SESSION

- A. Formal Papers
- B. Prepared Discussions
- C. Floor Discussions
- D. Other Observations and Comments Regarding Papers (Insights developed outside of the meeting room, possible sources of additional information, etc.)

*IV. CRITIQUE OF SESSION (Critically review the items in III, indicating matters such as how the research reports were received, their originality and quality)

*V. SIGNIFICANCE AND VALUE TO AMERICAN WATER POLLUTION RESEARCH ACTIVITIES (How might the reported results be applied to solve U. S. water pollution control problems? What research pertinent to U. S. needs is suggested by the reported research?)

*VI. INFORMATION AND OBSERVATIONS FROM THE CONFERENCE RELEVANT TO WATER POLLUTION RESEARCH BUT UNRELATED TO ASSIGNED SESSION (Pertinent information on global water pollution control research which was not presented at any of the formal sessions at the Conference.)

(Section VI will be separated from the remainder of the individual reports--begin on a separate sheet which includes your name.

---

*These headings are to be contained in each report

ATTACHMENT II

SCRIPT REQUIREMENTS

1. An original typed copy in double spacing and two copies should be submitted. The text must be ready for printing, and any substantial changes in proof other than typographical errors may be charged to the authors.

2. Half-tone illustrations should be restricted to the minimum necessary and the photographs may be on glossy not matte paper, enlarged sufficiently to permit their clear reproduction in half-tone. These must accompany the manuscript, preferably mounted on separate sheets. If words or numbers appear on photographs two copies are requested, one clearly printed and the other without inscription. If line drawings are already well drawn, it may be possible to reproduce them direct from the original, but in this case it is essential that the original drawings or good photo-prints should be provided. It is not possible to reproduce from "dyeline" prints or from prints with weak lines, and illustrations for reproduction should normally be about twice the final size required. All illustrations should be provided with descriptive legends and the illustrations should accompany manuscripts separately, with legends typed on a separate sheet. The manuscript and diagrams will be discarded one month after publication unless the publisher is requested to return original material to the author.

3. In the interests of economy and in order to avoid the introduction of errors, tables will be reproduced by photo-offset means directly from the authors' manuscripts.

(a) Look at current Tables in the Journal, and arrange your spatial layout of the Table to conform.

(b) Type should be clear and even, either on an electric typewriter with a carbon ribbon, or LETRASET.

(c) Tables, headings and legends should be typed on a separate sheet.

(d) Insert rules.

(e) Words normally italicized should be typed in italics or underlined.

4. References to published literature should be quoted in the text as follows: Smith (1950)—the date of publication, in parentheses, following the author's name. References should be listed together at the end of each paper and not given as footnotes. They should be arranged in alphabetical order (first author's surname) with the name of the periodical abbreviated in the style of the *World List of Scientific Periodicals* (4th edn, Butterworths, London, 1963–1965, 3 vols) and appear as follows:

Fermi E. and Marshall L. (1947) On the interaction between neutrons and electrons. *Phys. Rev.* **72,** 1139–1146.
Thring M. W. (1957) *Air Pollution*, p. 132. Butterworths, London.

It is particularly requested that (a) authors' initials (b) title of the paper and (c) the volume or part numbers and page numbers both beginning and end are given in every case.

5. Papers should be without unnecessary historical introduction.

USANC
REIMBURSEMENT REQUEST

Expenses incurred relating to preparation of interpretive analysis of the 9th Biennial International Water Pollution Control Conference, Stockholm, Sweden, June 12-16, 1978. The first column should show the total cost of developing the report including your services and expenses - the information is needed for cost sharing calculations. Show in the second column the actual reimbursement requested. Leave the third column blank.

ITEM	(1) AMOUNT	(2) REIMBURSEMENT REQUESTED	(3) REIMBURSEMENT APPROVED
Professional Services (collection/ assimilation/analysis of information, report preparation, etc.) ____days @ $________per day			
Conference Registration*			
Subsistence During Conference* ____days @ __________per day			
Travel Costs* --Within U.S.A. --International**			
TOTAL			

*Attach receipts (subsistence receipts required only if the amount exceeds 74 U.S. dollars per day

**No international travel costs are reimbursable, but should be included in the first column for cost sharing calculations.

____
Signature

____
Social Security Number

For Coordinating Subcommittee Use Only:

Report Received (Date)________________

Report Accepted and Reimbursement Approval (Date)_____________________

Date and Amount Paid__________________

Send this Voucher To:

Richard S. Engelbrecht
Department of Civil Engineering
University of Illinois at
Urbana-Champaign
Urbana, Illinois 61801